Casting Emission Reduction Program

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US Army Task N256

Ashland Iron/Furan No-Bake NBF

Technikon # RE 100119 DX

18 May 2001

This document was revised for unlimited public distribution.

AMERICAN FOUNDRY SOCIETY, INC.

UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH

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Pre-Production Air Emission Test Report

No-Bake Binder Systems

Furan / Iron

Emissions Test

RE100119DX

This report has been reviewed for completeness and accuracy and approved for release by the following:

Written by:	Scott Forbes	5/18/01 Date
Process Engineering Manager:	Steven Knight	5/23/01 Date
VP Measurement Technologies:	Clifford Glowacki, CIH	5-23-01 Date
VP Operations:	George Crandell	18 May'01 Date
President:	William Walden by CKG	5-23-01 Date

The data contained in this report were developed to assess the relative emissions profile of the product or process being evaluated against a standardized baseline process profile. You may not obtain the same results in your facility. Data was not collected to assess casting quality, cost, or producibility.

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Executive Summary

This report contains the results of emission testing to evaluate the pouring, cooling, and shakeout emissions from Test DX, a Furan No-Bake binder system, formulated for use with cast iron. These data are compared to results from Test DG, a reference or baseline Phenolic Urethane No-Bake binder system. All testing was conducted by Technikon, LLC in its Pre-Production foundry.

The Pre-Production Foundry is a simple general purpose manual foundry that was adapted and instrumented to make detailed organic emission measurements, using methods based on EPA protocols for pouring, casting cooling, and shakeout processes on *discrete* molds. The measurements are conducted under tightly controlled conditions not feasible in a commercial foundry. Evaluating a new product or process in the Technikon Pre-Production Foundry reduces the risk of new material or product introduction for the foundry industry.

The specific objective of Test DG was to establish air emission data against which the air emissions from new materials, equipment and processes, designed to reduce organic Hazardous Air Pollutants (HAPs) and Volatile Organic Compounds (VOCs) can be compared. This report documents the following test series: A comparison of Test DX (furan) to the reference Test DG (phenolic urethane).

The testing performed involved the collection of continuous air samples over a seventy-five minute period, including the mold pouring, cooling, shakeout, and post shakeout periods. Process and stack parameters were measured and include: the weights of the casting, mold, binder; Loss on Ignition (LOI) values for the mold prior to the test; metallurgical data; and stack temperature, pressure, volumetric flow rate and moisture content. The process parameters were maintained within prescribed ranges in order to ensure the reproducibility of the tests. Samples were collected and analyzed for over seventy (70) target compounds using procedures based on US EPA Method 18. Continuous monitoring of the Total Gaseous Organic Concentration (TGOC), formerly Total Hydrocarbon Content (THC), of the emissions was conducted according to US EPA Method 25A. Finally, the "condensable" organic material in the emissions was determined using a Technikon developed procedure. The "condensables" represent the "back half" catch from US EPA Method 5.

The mass emission rate of each parameter or target compound was calculated, in pounds per ton of metal, using the Method 25A data or the laboratory analytical results, the measured source data, and the weight of each casting. Results for structural isomers have been grouped and reported as a single entity. For example, ortho, meta, and para xylene are the three (3) structural isomers of dimethylbenzene and are reported as o,m,p-xylene though separate results are available in Appendix B of this report. Several "emissions indicators," in addition to the TGOC (THC) as Propane, were also calculated. The HC as Hexane results represent the sum of all organic compounds detected and expressed as hexane. All of the following sums are sub-groups of this measure. The "Sum of VOCs" is based on the sum of the individual target Volatile

Organic Compounds (VOCs) measured and includes the Hazardous Air Pollutants (HAPs) and Polycyclic Organic Material (POMs) listed in the Clean Air Act Amendments of 1990. The "Sum of HAPs" is the sum of the individual target HAPs measured and includes the POMs. Finally, the "Sum of POMs" is the sum of all of the polycyclic organic material measured.

Results for the emission indicators for Test DG and DX are shown in the following table. All results are reported as pounds emitted per ton of metal.

Emissions Indicators	Test DG	Test DX	% Change from DG
TGOC (THC) as Propane	12.2	2.62	-78%
HC as Hexane	11.1	1.72	-84%
Sum of VOCs	4.06	1.10	-73%
Sum of HAPs	2.00	1.08	-46%
Sum of POMs	0.104	0.006	-94%

The results from the above table show a decrease in emission indicators ranging from 46% to 94% for Test DX (Furan binder system) compared to DG (Phenolic Urethane binder system).

It must be noted that the reference and product testing performed is not suitable for use as emission factors or for purposes other than evaluating the *relative emission* reductions associated with the use of alternative materials, equipment, or processes. The emissions measurements are unique to the specific castings produced, materials used, and testing methodology associated with these tests, and should not be used as the basis for estimating emissions from actual commercial foundry applications.

1.0 Introduction

1.1 Background

Technikon LLC is a privately held contract research organization located in McClellan, California, a suburb of Sacramento. Technikon offers emissions research services to industrial and government clients specializing in the metal casting and mobile emissions areas. Technikon operates the Casting Emission Reduction Program (CERP). CERP is a cooperative initiative between the Department of Defense (US Army) and the United States Council for Automotive Research (USCAR). Its purpose is to evaluate alternative casting materials and processes that are designed to reduce air emissions and/or produce more efficient casting processes. Other technical partners directly supporting the project include: the American Foundry Society (AFS); the Casting Industry Suppliers Association (CISA); the US Environmental Protection Agency (USEPA); and the California Air Resources Board (CARB).

1.2 CERP Objectives

The primary objective of CERP is to evaluate materials, equipment, and processes used in the production of metal castings. Technikon's facility was designed to evaluate alternate materials and production processes designed to achieve significant air emission reductions, especially for the 1990 Clean Air Act Amendment HAPs. The facility has two principal testing arenas: a Pre-Production Foundry designed to measure airborne emissions from individually poured molds, and a Production Foundry designed to measure air emissions in a continuous full scale production process. Each of these testing arenas has been specially designed to facilitate the collection and evaluation of airborne emissions and associated process data. The data collected during the various testing projects are evaluated to determine both the airborne emissions impact of the materials and/or process changes, and their stability and impact upon the quality and economics of casting and core manufacture. The materials, equipment, and processes may need to be further adapted and defined so that they will integrate into current casting facilities smoothly and with minimum capital expenditure.

Normally, Pre-Production testing is conducted first in order to evaluate the air emissions impact of a proposed alternative material, equipment, or process in the most cost effective manner. The Pre-Production Foundry is a simple general purpose manual foundry that was adapted and instrumented to make detailed emission measurements using methods based on EPA protocols for pouring, casting cooling, and shakeout processes on *discrete* molds under tightly controlled conditions not feasible in a commercial foundry. The Pre-Production Foundry uses a four-cavity, AFS irregular gear mold as its test pattern for No-Bake testing. All No-Bake testing occurs in the Pre-Production Foundry.

The Production Foundry's design as a basic greensand foundry was deliberately chosen so that whatever is tested in this facility will also be convertible to existing mechanized commercial foundries. The type and size of equipment, materials, and processes used emulate an automotive foundry. This facility is used to evaluate materials, equipment, and processes in a *continuous* process that is allowed to vary to the limits of commercial experience in a controlled manner. The Production Foundry provides simultaneous detailed individual emission measurements using methods based on US EPA protocols of the melting, pouring, sand preparation, mold making, and core making processes. It is instrumented so that the data on all activities of the metal casting process can be simultaneously and continuously collected, in order to completely evaluate the economic impact of the prospective emission reducing strategy. The Production Foundry's test casting is a single cavity Ford Motor Company I-4 engine block. Castings are randomly selected to evaluate the impact of the material, equipment, or process on casting quality. Alternative materials, equipment, and processes that demonstrate significant air emission reduction potential, preserve casting quality parameters, and that are economically viable based on the Pre-Production testing, may be further evaluated in the Production Foundry.

It must be noted that the results from the reference and product testing performed are not suitable for use as emission factors or for other purposes other than evaluating the *relative emission reductions* associated with the use of alternative materials, equipment, or manufacturing processes. The emissions measurements are unique to the specific castings produced, materials used, and testing methodology associated with these tests. These measurements *should not* be used as the basis for estimating emissions from actual commercial foundry applications.

1.3 Report Organization

This report has been designed to document the methodology and results of a specific test plan that was used to evaluate the performance of an alternative material, equipment, or process in the Pre-Production Foundry. Section 2 of this report includes a summary of the methodologies used for data collection and analysis, emission calculations, QA/QC procedures, and data management and reduction methods. Specific data collected during this test are summarized in Section 3 of this report, with detailed data included in Appendices B and C of this report. Section 4 of this report contains a discussion of the results.

The raw data for this test series are included in a data binder that is maintained at the Technikon facility. There are several support documents that provide details regarding the testing and analytical procedures used. Appendix F contains a listing of these support documents.

1.4 Preliminary Testing

The foundation for the specific test protocols and airborne emission measurements have been determined from testing performed to:

- Establish the required number of samples needed to statistically support the evaluation of emission reduction potentials of the alternative materials, equipment, and processes that may be evaluated;
- Provide a series of standardized emissions from standard mold packages.

The results of this preliminary testing is included in a report entitled Evaluation of the Required Number of Replicate Tests to Provide Statistically Significant Air Emission Reduction Comparisons for the CERP Pre-Production Foundry Test Program.

1.5 Specific Test Plan and Objectives

This report contains the results of testing performed to assess the emission reduction potential of two different No-bake binder systems. The test hypothesis is that the test binder system will have lower VOC and HAP emissions than a reference (baseline) No-Bake binder system. Because Test DX is among the first Furan No-Bake binder systems to be tested at the Technikon facility, comparison to a Phenolic Urethane No-Bake system was needed. Table 1-1 provides a summary of the test plans. The details of the approved test plans are included in Appendix A.

Table 1-1 Test Plan Summary

	Test Plans	
Type of Process tested	No-Bake Phenolic Urethane	No-Bake Furan
Test Plan Number	RE100102DG	RE100119DX
Binder System	Delta HA TECHNISET® 20-665/23-635/17-727	Ashland Specialty Chemical Co. NBF-1 and NBF-4
Metal Poured	Iron	Iron
Casting Type	Four-cavity AFS Irregular Gear Mold	
Number of molds poured	12/27/00	7
Test Dates	11-13-00 > 11-15-00	1-25-01 > 1/30/01
Emissions Measured	70 organic HAPs and VOCs	
Process Parameters Measured	Total Casting, Mold and Binder Weights, Metallurgical data, % LOI, Stack Temperature, Stack Moisture Content, Stack Pressure, and Stack Volumetric Flow Rate	

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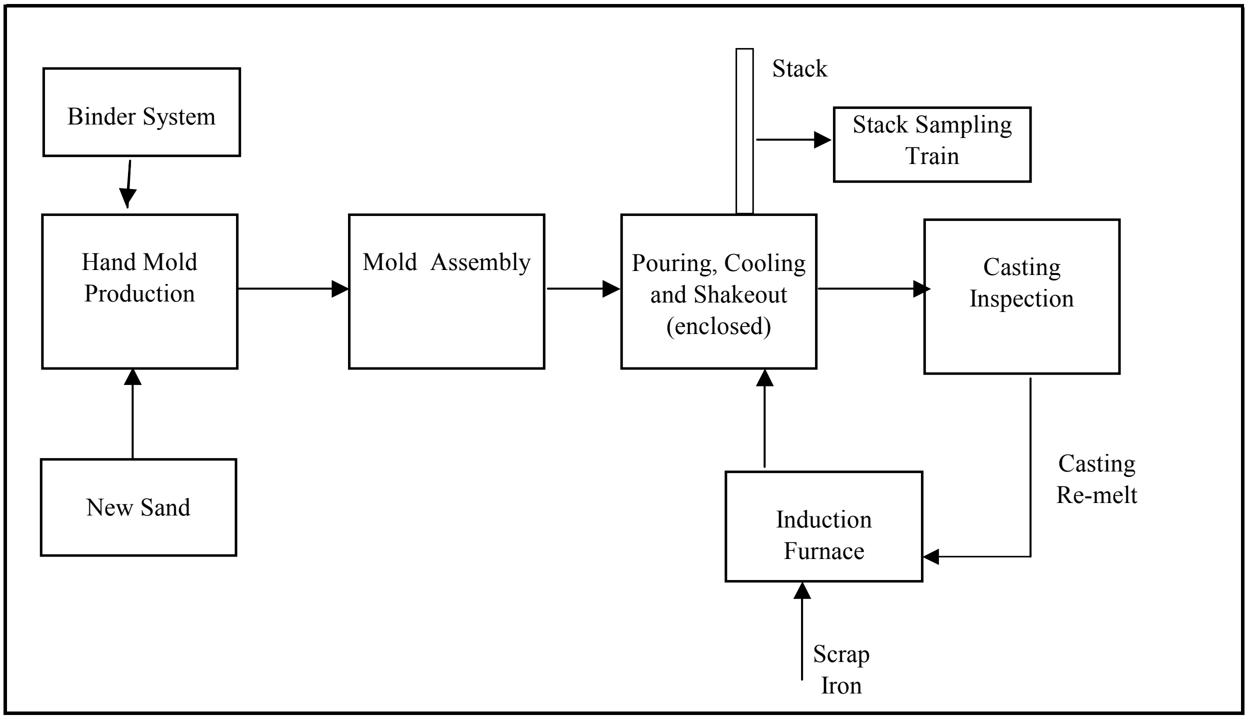
2.0 Test Methodology

2.1. Description of Process and Testing Equipment

Figure 2-1 is a diagram of the Pre-Production Foundry process equipment.

Figure 2-1 Pre-Production Foundry Layout Diagram



2.2 Description of Testing Program

The specific steps used in this sampling program are summarized below:

1. **Test Plan Review and Approval:** The proposed test plan was reviewed by the Technikon staff and CTC Program Manager, and approved.

2. **Mold and Metal Preparation:** The molds are prepared to a standard composition by the Technikon production team. Relevant process data are collected during mold preparation. Iron is melted in a 1000 lb. Ajax induction furnace (Model MFB-1000). The amount of

No-Bake Mold Preparation

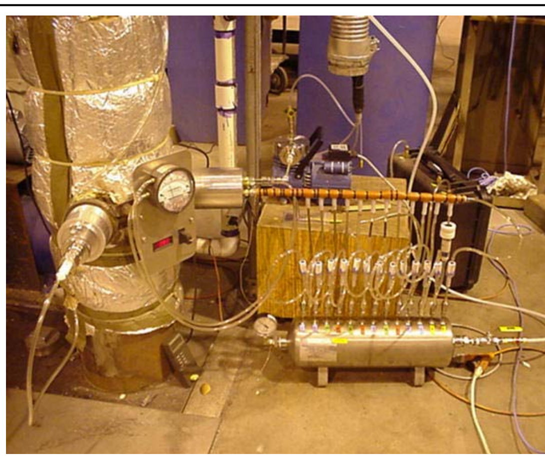
metal melted is determined from the poured weight of the casting and the number of molds to be poured. The metal composition is prescribed by a metal composition worksheet. The weight of metal poured into each mold is recorded on the process data summary sheet.

Pouring of Molds Through Opening in Collection Hood

3. **<u>Individual Sampling Events:</u>** Replicate tests are performed on several mold packages. The mold packages are each placed into an enclosed test stand. Iron is poured through an opening in the top of the enclosure. The opening is closed as soon as pouring is completed. Continuous air samples are collected during the forty-five minute pouring and cooling process, during the fifteen minute shakeout of the mold, and for an additional fifteen minute period following shakeout. The total sampling time is seventy-five minutes.

The weight of each mold and the weight of binder used to prepare that mold are recorded on the Process Data Summary Sheet. In addition, the pouring temperature, number of cavities poured, the %LOI of the mold before pouring are also recorded on the Process Data Summary Sheet. The unheated emission hood is ventilated at approximately 700 SCFM through a 12-inch diameter heated duct. Emissions samples are drawn from sampling ports located to ensure conformance with EPA Method 1. The tip of the probe is located in the centroid of the duct.

Castings after Shake Out



Volatiles and Condensables Sampling

4. **<u>Process Parameter Measurements:</u>** Table 2-1 lists the process parameters that are monitored during each test. The analytical equipment and methods used are also listed.

Table 2-1 Process Parameters Measured

Parameter	Analytical Equipment and Methods
Mold Weight	Acme 4260 Crane Scale (Gravimetric)
Casting Weight	Westweigh PP2847 Platform Scale (Gravimetric)
Binder Weight	Mettler PJ8000 Digital Scale (Gravimetric)
Sand Resin Tensile Strength	Dietert 405 Universal Strength Machine
Tensile Test Bar Weight	Mettler PJ 4000 Digital Scale (Gravimetric)
LOI, %	Denver Instruments XE-100 Analytical Scale (AFS procedure 321-87-S)
Metallurgical Parameters	
Pouring Temperature	Electro-Nite DT 260 (T/C immersion pyrometer)
Carbon/Silicon, and Fusion Temperature	Electro-Nite Datacast 2000 (Thermal Arrest)
Alloy Weights	OHAUS MP-2
Carbon/Silicon	Baird Foundry Mate Optical Emission Spectrometer

5. **Air Emissions Analysis:** The specific sampling and analytical methods used in the Pre-Production Foundry tests are based on the USEPA reference methods shown in Table 2-2. The details of the specific testing procedures and their variance from the reference methods are included in the Technikon Emissions Testing and Analytical Testing Standard Operating Procedures.

Table 2-2 Sampling and Analytical Methods

Measurement Parameter	Test Method
Port location	EPA Method 1
Number of traverse points	EPA Method 1
Gas velocity and temperature	EPA Method 2
Gas density and molecular weight	EPA Method 3a
Gas moisture	EPA Method 4, gravimetric
HAPs	EPA Method 18, TO11, NIOSH 2002*
VOCs	EPA Method 18, 25A, TO11, NIOSH 2002*
Condensables	Technikon method **

*These methods were specifically modified to meet the testing objectives of the CERP Program.
**The Technikon condensables method is intended to provide a measure of the EPA Method 5 "back-half" determination.

6. **<u>Data Reduction, Tabulation and Preliminary Report Preparation</u>:** The analytical results of the emissions tests provide the mass of each analyte in the sample. The total mass of the analyte emitted is calculated by multiplying the mass of analyte in the sample times the ratio of total stack gas volume to sample volume. The total stack gas volume is calculated from the measured stack gas velocity and duct diameter, and corrected to dry standard conditions using the measured stack pressures, temperatures, gas molecular weight and moisture content. The total mass of analyte is then divided by the weight of the casting poured to provide emissions data in pounds of analyte per ton of metal.

   The results of each of the sampling events are included in Appendix B of this report. The results of each test are also averaged and are shown in Table 3-1.

7. **<u>Report Preparation and Review</u>:** The Preliminary Draft Report is reviewed by the Process Team and Emissions Team to ensure its completeness, consistency with the test plan, and adherence to the prescribed QA/QC procedures. Appropriate observations, conclusions and recommendations are added to the report to produce a Draft Report. The Draft Report is reviewed by the Vice President-Measurement Technologies, the Vice President-Operations, and the Technikon President. Comments are incorporated into a draft Final Report prior to final signature approval and distribution.

2.3 Quality Assurance and Quality Control (QA/QC) Procedures

Detailed QA/QC and data validation procedures for the process parameters, stack measurements, and laboratory analytical procedures are included in the <u>Technikon Emissions Testing and Analytical Testing Standard Operating Procedures.</u> In order to ensure the timely review of critical quality control parameters, the following procedures are followed:

- Immediately following the individual sampling events performed for each test, specific process parameters are reviewed by the Manager - Process Engineering to ensure that the parameters are maintained within the prescribed control ranges. Where data are not within the prescribed ranges, the Manager - Process Engineering and the Vice President-Operations determine whether the individual test samples should be invalidated or flagged for further analysis following review of the laboratory data.

- The source (stack) and sampling parameters, analytical results and corresponding laboratory QA/QC data are reviewed by the Emissions Measurement Team to confirm the validity of the data. The VP-Measurement Technologies reviews and approves the recommendation, if any, that individual sample data should be invalidated. Invalidated data are not used in subsequent calculations.

3.0 Test Results

The average emission results, in pounds per ton of metal poured, is presented in Table 3-1 for tests reported in this document. This table includes the individual VOC compounds that comprise at least 95% of the total VOCs measured, along with the corresponding sum of VOCs, sum of HAPs, and sum of POMs. The table also includes the TGOC (THC) as Propane, HC as Hexane and the percentage difference between the baseline (DG) and the test system (DX). Percentage differences in **bold** are the result of emissions differences, not test variability. Figures 3-1, 3-2, and 3-3 represent the comparisons of the five emissions indicators and selected individual HAP and VOC emissions data from Table 3-1 in graphical form. Appendix B contains the detailed data including the results for all analytes measured. Table 3-2 includes the averages of the key process and source parameters and the data target ranges. Detailed process and source data are presented in Appendix C.

Method 25A charts for the tests are included in Appendix D of this report. The charts are presented to show the VOC profile of emissions for each pour.

A laboratory analytical data validation log is maintained in the Technikon offices..

Table 3-1 Summary of Test Plan DG and DX Average Results

Analytes	Test DG (Lbs/Ton)	Test DX (Lbs/Ton)	% Change from DG
TGOC (THC) as Propane	12.2	2.62	-78%
HC as Hexane	11.1	1.72	-84%
Sum of VOCs	4.06	1.10	-73%
Sum of HAPs	2.00	1.08	-46%
Sum of POMs	0.104	0.006	-94%
	Individual Organic HAPs		
Phenol	0.942	0.044	-95%
o,m,p-Cresol	0.500	ND	-100%
Benzene	0.299	0.818	174%
Dimethylnaphthalenes	0.086	ND	-100%
Toluene	0.056	0.106	90%
Formaldehyde	0.021	0.025	23%
Acetaldehyde	0.004	0.066	1521%
	Other VOCs		
Dimethylphenols	1.07	ND	-100%
Diethylbenzenes	0.299	ND	-100%
Trimethylbenzenes	0.216	ND	-100%
Tetradecane	0.141	ND	-100%
Butylbenzenes	0.116	ND	-100%
Dodecane	0.060	ND	-100%
Indan	0.057	ND	-100%
Undecane	0.033	ND	-100%
	Other Analytes		
Carbon Monoxide	4.18	5.99	43%
Methane	0.590	0.352	-40%
Carbon Dioxide	59.3	47.1	-21%
Condensables	0.800	2.28	185%

Individual results shown constitute >95% of mass of all detected VOCs

ND: Non Detect

"Percent Change from Test DG" values in bold indicate a 95% probability that the differences in the average values were not from test variability.

All “**other Analytes**” are not included in the sum of HAPS or VOCs.

Table 3-2 Summary of Test Plan DG and DX Process and Stack Parameters

Average Process and Stack Parameters	Average of Baseline DG	Average of Test DX (Iron)	% Difference	Target Range
Casting Metal Weight, casting & sprue, lbs.	131	133	1.5	130 - 138
Pouring Temperature, °F	2639	2630	-0.3	2615 - 2645
No Bake Mold Weight, lbs.	332	386	16.3	330 - 395
% Resin (part I) + co-reactant (part II) BOS	1.14	1.30	14.0	1.1-1.3
Ratio Resin (part I) to co-reactant (part II)	55/45	100/40	-	N / A
True % Resin & co-reactant (part I +part II)	1.12	1.28	14.3	1.1- 1.30
True % Resin, co-reactant, & catalyst (part I +part II + part III)	1.17	1.79	53.0	1.1 - 1.80
No Bake Mold LOI, % 1400°F	1.41	2.26	60.3	1.4 – 2.5
Dog Bone Tensile Strength 2 hrs, psi	208	82	-60.6	N/A
Dog Bone Tensile Strength 24 hrs at 90% RH, psi	87	108	24.7	75-110
Average Stack Temperature, □F	105	106	1.0	110 ±10
Total Moisture Content, %	0.89	0.96	7.9	N/A
Average Stack Velocity, ft./sec.	16.0	16.0	0.2	15 ± 2
Avg. Stack Pressure, in. Hg	30.17	30.24	0.2	NA
Stack Flow Rate, scfm	705	707	0.3	700 ± 50

N/A: Not Applicable

Figure 3-1 Comparison of Emission Indicators from Test DG and DX

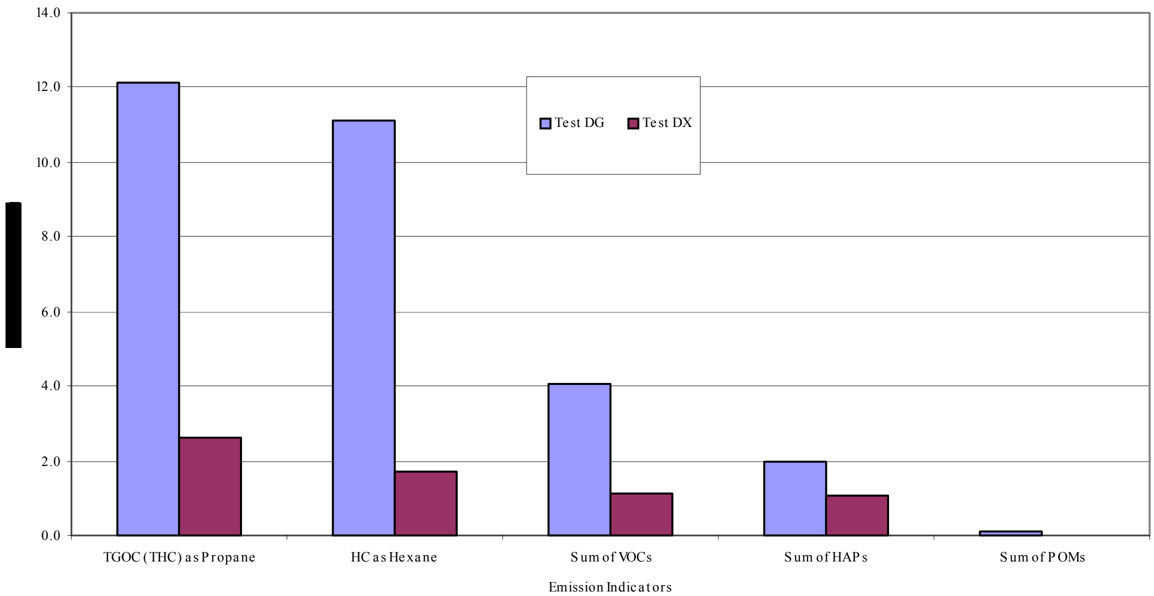


Figure 3-2 Comparison of Selected HAP Emissions from Test DG and DX

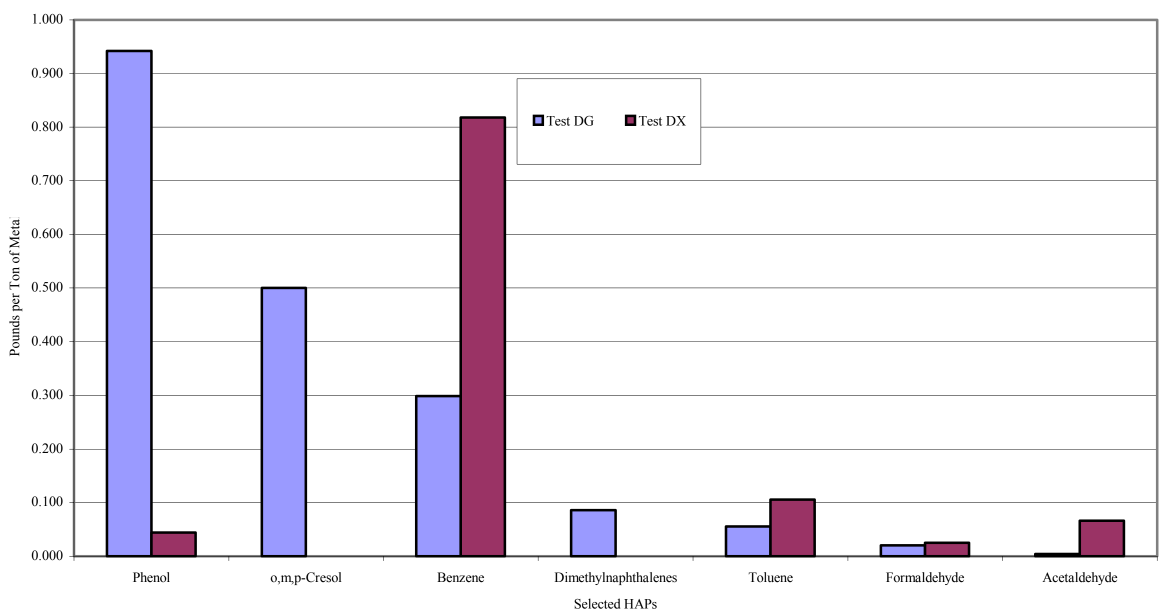
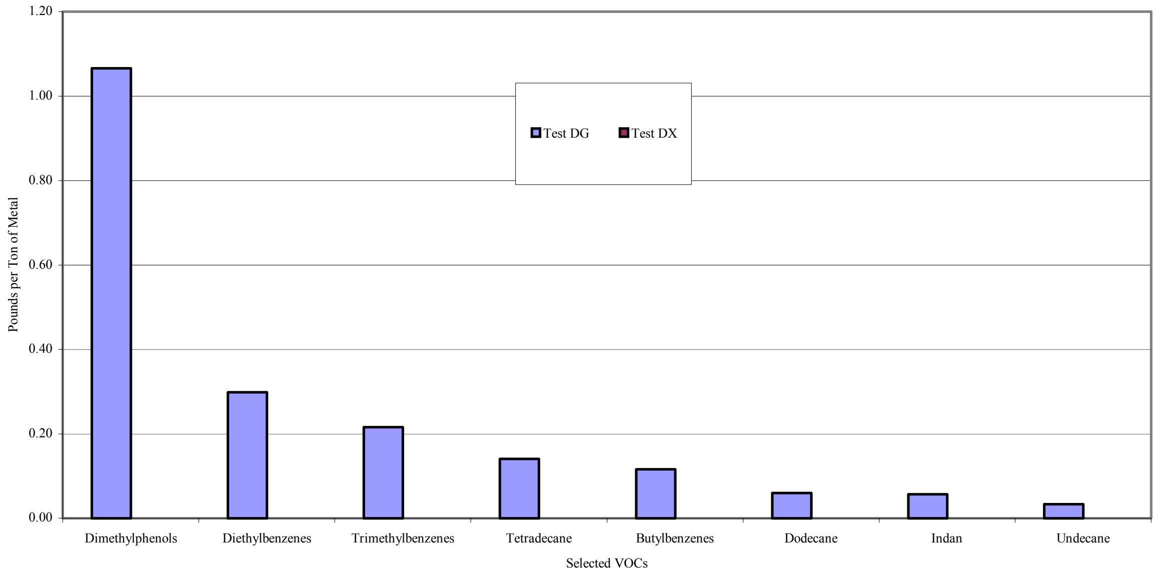


Figure 3-3 Comparison of Selected VOC Emissions from Test DG and DX



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4.0 Discussion of Results

The sampling and analytical methodologies were the same for Test Plans DG and DX. Observation of measured process parameters indicates that the validated tests were run within an acceptable range. In Table 3-1, the "percent change from Test DG" values presented in **bold** letters indicate a greater than 95% probability that the differences in the average values were not the result of variability in the test protocol determined from T-Statistic calculations. A table showing the T-Statistics calculated is found in Appendix B.

A total of seven (7) test pours were performed for the Test Series DX. Six (6) test pours were validated, and results were used during calculations of the reported averages.

The results of the tests performed for the comparison of Test DX to Test DG show a 78% reduction in TGOC (THC) as propane, an **84%** reduction in HC as hexane, a 73% reduction in VOCs, a 46% reduction in HAPs, and a **94%** reduction in POMs. The furan system (DX) included testing for two additional analytes: furfural and furfuryl alcohol. Only furfural was detected and results for both analytes may be found in Appendix B.

Test DX showed almost equivalent results for total VOCs as total HAPs. The VOCs detected that were not HAPs comprised only 1.8% of the Sum of VOCs. Benzene was found in the largest amount with toluene following next.

The chemistry of a phenolic urethane binder system is different than a furan binder. Different results from the two methods can be expected. The comparison of Test DX to DG provides only a reference benchmark.

EPA Method 25A, TGOC (THC) as propane, is weighted to the detection of more volatile hydrocarbon species, beginning at C1 (methane), with results calibrated against a three-carbon alkane (propane). HC as hexane is weighted to detection of relatively less volatile compounds and detects hydrocarbon compounds in the alkane range between C6 and C16, with results calibrated against a six-carbon alkane (hexane).

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APPENDIX A APPROVED TEST PLANS FORTEST SERIES DG AND DX

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TECHNIKON/CERP TEST PLAN

> **CONTRACT NUMBER:** 1256 **TASK NUMBER:** 120

> **CONTROL NUMBER:** RE 1 00102

> **SAMPLE FAMILY:** DG

> **SAMPLE EVENTS:** 001 thru 021

> **SITE:** X **PRE-PRODUCTION(243)** ___ **CERP FOUNDRY(238)**

> **TEST TYPE:** Iron: No-Bake Phenolic Urethane Baseline

> **MOLD TYPE:** No-Bake variable-tooth gear precision mold made with Delta-HA Techniset® No-Bake 20-665 Part I, 23-635 Part II, 17-727 Part III

> **CORE TYPE:** N/A

> **TEST DATE:** **START:** 13 Nov 00
FINISH: 27 Dec 00

TEST OBJECTIVES:

Primary: To measure emissions from No-Bake molds, formulated for use with cast iron, and manufactured based on protocols developed in capability study CP and CW to make a No-Bake Iron baseline. The Airsense real-time spectrometer & THC analyzer will be used to monitor the test, and sample tubes will be collected for analysis by an outside laboratory.

VARIABLES: Three part No-Bake resin at 1.1% resin (BOS) in the ratio of 55% Delta-HA Techniset® 20-665 resin, 45% Delta-HA Techniset® 23-635 co-reactant, and 7% (BOR Part I) Delta-HA Techniset® 17-727 part III activator.

BRIEF OVERVIEW: The molds will be the standard 4-on variable-tooth gear made from Okie 90 silica sand with the above resin system. The molds will be transferred to the Pouring/cooling/shakeout hooded station used for greensand and core baselines.

SPECIAL CONDITIONS: A shakeout fixture, which will promote disintegration of the No-Bake mold shall be installed on the shakeout device. This fixture will carry the No-Bake mold and locate the pouring basin in the standard pouring position. Steel hangers will be implanted in each cavity to promote separation of castings from the no bake sand during shakeout.

Manager Process Engineering (Technikon)	11/9/00 **Date**
V.P. Measurement Technologies (Technikon)	11-9-00 **Date**
V.P. Operations (Technikon)	11-9-00 **Date**
Emissions Team (USCAR)	12/5/00 **Date**
Process and Facilities Team (USCAR)	12/5/00 **Date**
Project Manager (CTC)	12/12/00 **Date**

Series DG

Pre-Production Phenolic Urethane / Iron No-Bake Process Instructions -

A. Experiment

1. Establish a Phenolic Urethane Iron No-Bake baseline that other No-Bake vendor materials will be compared.

B. Materials

1. No-Bake molds: Okie 90 Silica Sand and

   a) 1.1% Delta-HA Techniset ® No-Bake Phenolic-Urethane core resin composed of 20-665 part I resin, 23-635 part II co-reactant, & 17-727 part III activator. This resins are designed for iron applications.

2. Metal: Class 30 Gray cast iron

Note: Observe all safety precautions attendant to these operations as delineated in the Pre-Production operating and safety instruction manual.

C. Mold Requirements

1. Make nine (9) Phenolic No-Bake molds according standards determined in CW & CP capability studies.

D. Phenolic Urethane No-Bake Core Sand preparation

1. The phenolic urethane No-Bake sand shall be 1.1% total resin (BOS), Part I/Part II ratio 55/45, Part III at 7% of Part I.
2. 2Calibrate the Kloster No-Bake sand mixer to dispense 240 pounds/min more or less.
3. Calibrate the resin pumps:

   a) Part I: Based on the actual measured sand dispensing rate calibrate the Part I resin to be 55% of 1.1% total resin or 0.605% +/- .01% (BOS).
   b) Part II: Based on the actual measured sand dispensing rate calibrate the Part II co-reactant to be 45% of 1.1% total resin or 0.495% +/- 0.01% (BOS).
   c) Calibrate the part III activator to be 7% +/- 0.1% of Part I.

E. Dog bones

1. Make 24 dogbones according to the protocol establish in capability study CW (Two (2) 12-piece sets of test dogbones using 12-on core box).

2. Sample the raw uncoated sand from the hopper feeding the core sand mixer, bag, label with date, time, and mold number. Send to sand lab for LOI comparison.
3. Place the core box on the vibrating compaction table.
4. Start the Kloster mixer and waste a few pounds of sand.
5. Flood the core box with sand then stop the mixer.
6. Strike off the core box to ½ inch deep
7. Turn on the vibrating compaction table for 15 seconds.
8. Screed off most of the excess sand.
9. Screed the core box a second time moving very slowly in a back and forth manner to remove **all** excess sand.

   Note: It is important to neither gouge the sand nor leave excess sand in center neck portion of the dogbone or the test results will be affected

10. Set aside for about 6-7 minutes or until hard to the touch.
11. Carefully remove the cores from the core box by separating the core box components.
12. Place 6 bones in the 90% Rh cabinet.
13. Perform tensile tests on 6 bones at each of the following times after dogbone manufacture: 30 minutes, 2 hours, 24 hours, and 24 hours@ 90% Rh. Report the average and standard deviation for each set of six (6) at each time for each mold.
14. Weigh each dogbone and record the weight to the nearest 0.1 grams using the PJ 4000 electronic scale at the time it is tensile tested.

    Note: maintain the correlation between the reported weight of a dogbone and its tensile strength and scratch hardness.

15. Run a 1400^{o} F core LOI on three (3) of the 30- minute tensile test dogbones. Report the average value for each mold.
16. Run a 1400^{o} F core LOI on the raw uncoated sand sampled at the same time as the dogbones are made. Calculate a Core Resin LOI as the difference between the average Core LOI and raw sand core LOI. Report this value for each mold.

F. No-Bake mold making: 4 on gear core box

1. Inspect the box for cracks and other damage. Repair before use.
2. Prepare the core box halves with a light coating of Ashland Zipslip® IP 78. Allow to fully dry.
3. Place the drag core box on the vibrating compaction table.
4. Begin filling the box.
5. Immediately start the table vibration.
6. Manually spread the sand around the box as it is filling.
7. Strike off the box until it is full.
8. Allow the vibrator to run an additional 10 seconds after the box is full.
9. Strike off the core box so that the core mold is 5-1/2 inches thick.
10. Set the core box aside for 5 to 6 minutes or until it is hard to the touch.
11. Invert the box and place on a transport pallet.

12. Remove the pivot hole pins.
13. Remove the core mold half by tapping lightly on the box with a soft hammer.
14. Set the drag core box aside.
15. Place the cope core box on the vibrating compaction table.
16. Follow steps F3-F13 except that the cope mold is 5 inches thick.
17. Rotate the unboxed core to set it on edge.
18. Drill vent holes as per template.
19. Hand trim the pour basin to promote minimum splash and minimum cup volume.
20. Close cope onto drag. Visually check for closure.
21. Install two (2) steel straps, one on either side of the pouring cup, with 4 metal corner protectors each to hold the mold tightly closed.
22. Weigh and record the weight of the closed mold.

G. Emission hood

1. Loading

a) Hoist the mold onto the shakeout deck fixture within the emission hood with the pouring cup side toward the furnace.
b) Install the cope weighting device.
c) Install a half inch re-rod casting hangers through the cope into each of the four riser cavities and suspend them over the horizontal mold retaining bars.
d) Close, seal, and lock the emission hood

H. SHAKEOUT

a) After 45 minutes of cooling time has elapsed turn on the shakeout unit and run for 15 minutes as prescribed in the emission test plan from pouring.
b) Turn off the shakeout. The emission sampling will continue for an additional 15 minutes or a total of 75 minutes
c) Wait for the emission team to signal that they are finished sampling.
d) Open the hood, remove the castings
e) Clean core sand out of the pit and off the shakeout.
f) Weigh and record cast metal weight.

I. H. Melting

1. Initial charge

a) Charge the furnace according to the *Generic Start Up Charge for Pre-Production* heat recipe bearing effectivity date 18 Mar 1999.
b) Place part of the steel scrap on the bottom, followed by carbon alloys, and the balance of the steel.
c) Place a pig on top on top.
d) Bring the furnace contents to the point of beginning to melt over a period of 1 hour at reduced power.

- **e)** Add the balance of the metallics under full power until all is melted and the temperature has reached 2600 to 2700^o F.
- **f)** Slag the furnace and add the balance of the alloys.
- **g)** Raise the temperature of the melt to 2700 ^{o}F and take a DataCast 2000 sample. The temperature of the primary liquidus (TPL) must be in the range of 2200-2350^o F.
- **h)** Hold the furnace at 2500-2550^{o}F until near ready to tap.
- **i)** When ready to tap raise the temperature to 2700^{o}F and slag the furnace.
- **j)** Record all metallic and alloy additions to the furnace, tap temperature, and pour temperature. Record all furnace activities with an associated time.

2. Back charging

- **a)** If additional iron is desired back charge according to the *Generic Pre-Production Last Melt* heat recipe bearing effectivity date 18 Mar 1999.
- **b)** Charge a few pieces of steel first to make a splash barrier, followed by the carbon alloys.
- **c)** Follow the above steps beginning with H.1.e

3. Emptying the furnace

- **a)** Pig the extra metal only after the last emission measurement is complete to avoid contaminating the air sample.
- **b)** Cover the empty furnace with ceramic blanket to cool.

J. Pouring

1. Preheat the ladle.

- **a)** Tap 400 pounds more or less of 2700^o F metal into the cold ladle.
- **b)** Casually pour the metal back to the furnace.
- **c)** Cover the ladle.
- **d)** Reheat the metal to 2780 +/- 20^o F.
- **e)** Tap 450 pounds more or less of iron into the ladle while pouring inoculating alloys onto the metal stream near its base.
- **f)** Cover the ladle to conserve heat.
- **g)** Move the ladle to the pour position, open the emission hood pour door and wait until the metal temperature reaches 2630 +/- 10^o F.
- **h)** Commence pouring keeping the sprue full.
- **i)** Upon completion close the hood door, return the extra metal to the furnace, and cover the ladle.

Steven Knight
Manager, Process Engineering

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/13/00											No-Bake Iron, 1.1% Resin
EVENT 1											
AIRSENSE	DG00101										TOTAL
THC	DG00102										TOTAL
PUF	DG00118								35L		Port B
11/13/00											No-Bake Iron, 1.1% Resin
EVENT 2											
AIRSENSE	DG00201										TOTAL
THC	DG00202										TOTAL
PUF	DG00210								35L		Port B
11/13/00											No-Bake Iron, 1.1% Resin
EVENT 3											
AIRSENSE	DG00301										TOTAL
THC	DG00302										TOTAL
PUF	DG00310								35L		Port B
11/14/00											
EVENT 4											
PUF	DG004								35L		Port B

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/14/00											
EVENT 5											
AIRSENSE	DG00501	X									TOTAL
THC	DG00502	X									TOTAL
M-18	DG00503		1						25	1	TOTAL
M-18	DG00504					1			25	1	TOTAL
M-18	DG00505		1						25	2	TOTAL
M-18	DG00506					1			25	2	TOTAL
M-18 by MS	DG00507		1						25	3	TOTAL
M-18 by MS	DG00508					1			25	3	TOTAL
M-18 by MS	DG00509		1						25	4	TOTAL
M-18 by MS	DG00510					1			25	4	TOTAL
EXCESS									25	5	Excess
NIOSH 1500	DG00511		1						500	6	TOTAL Orbo 32L
EXCESS									500	7	Excess
NIOSH 2002	DG00512		1						500	8	TOTAL (SKC 226-15)
EXCESS									500	9	Excess
TO11	DG00513		1						1000	10	TOTAL
TO11	DG00514					1			1000	10	TOTAL
EXCESS									1000	11	Excess
Moisture			1						500	12	
Excess									5000	13	Excess
PUF	DG00515		1						35L		Port B

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/14/00											
EVENT 6											
AIRSENSE	DG00601	X									TOTAL
THC	DG00602	X									TOTAL
M-18	DG00603		1						25	1	TOTAL
M-18	DG00604			1					25	2	TOTAL
M-18 by MS	DG00605		1						25	3	TOTAL
M-18 by MS	DG00606			1					25	4	TOTAL
Excess									25	5	excess
NIOSH 1500	DG00607		1						500	6	TOTAL Orbo 32L
NIOSH 1500	DG00608			1					500	7	TOTAL Orbo 32L
NIOSH 2002	DG00609		1						500	8	TOTAL (SKC 226-15)
NIOSH 2002	DG00610			1					500	9	TOTAL (SKC 226-15)
TO11	DG00611		1						1000	10	TOTAL
TO11	DG00612			1					1000	11	TOTAL
Moisture			1						500	12	
Excess									5000	13	excess
PUF	DG00613		1						35L		Port B

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/14/00											
EVENT 7											
AIRSENSE	DG00701	X									TOTAL
THC	DG00702	X									TOTAL
M-18	DG00703		1						25	1	TOTAL
M-18	DG00704			1					25	2	TOTAL
M-18 by MS	DG00705		1						25	3	TOTAL
M-18 by MS	DG00706			1					25	4	TOTAL
EXCESS									25	5	Excess
NIOSH 1500	DG00707		1						500	6	TOTAL Orbo 32L
EXCESS									500	7	Excess
NIOSH 2002	DG00708		1						500	8	TOTAL (SKC 226-15)
EXCESS									500	9	Excess
TO11	DG00709		1						1000	10	TOTAL
EXCESS									1000	11	Excess
Moisture			1						500	12	
Excess									5000	13	Excess
PUF	DG00710		1						35L		Port B

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/15/00											
EVENT 8											
AIRSENSE	DG00801	X									TOTAL
THC	DG00802	X									TOTAL
M-18	DG00803		1						25	1	TOTAL
M-18	DG00804			1					25	2	TOTAL
M-18 by MS	DG00805		1						25	3	TOTAL
M-18 by MS	DG00806			1					25	4	TOTAL
EXCESS									25	5	Excess
NIOSH 1500	DG00807		1						500	6	TOTAL Orbo 32L
EXCESS									500	7	Excess
NIOSH 2002	DG00808		1						500	8	TOTAL (SKC 226-15)
EXCESS									500	9	Excess
TO11	DG00809		1						1000	10	TOTAL
EXCESS									1000	11	Excess
Moisture			1						500	12	
Excess									5000	13	Excess
PUF	DG00810		1						35L		Port B

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/15/00											
EVENT 9											
AIRSENSE	DG00901	X									TOTAL
THC	DG00902	X									TOTAL
M-18	DG00903		1						25	1	TOTAL
M-18	DG00904			1					25	2	TOTAL
M-18 by MS	DG00905		1						25	3	TOTAL
M-18 by MS	DG00906			1					25	4	TOTAL
EXCESS									25	5	Excess
NIOSH 1500	DG00907		1						500	6	TOTAL Orbo 32L
EXCESS									500	7	Excess
NIOSH 2002	DG00908		1						500	8	TOTAL (SKC 226-15)
EXCESS									500	9	Excess
TO11	DG00909		1						1000	10	TOTAL
EXCESS									1000	11	Excess
Moisture			1						500	12	
Excess									5000	13	Excess
PUF	DG00910		1						35L		Port B

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/15/00											
EVENT 10											
AIRSENSE	DG01001	X									TOTAL
THC	DG01002	X									TOTAL
M-18	DG01003		1						25	1	TOTAL
M-18	DG01004			1					25	2	TOTAL
M-18 by MS	DG01005		1						25	3	TOTAL
M-18 by MS	DG01006			1					25	4	TOTAL
EXCESS									25	5	Excess
NIOSH 1500	DG01007		1						500	6	TOTAL Orbo 32L
EXCESS									500	7	Excess
NIOSH 2002	DG01008		1						500	8	TOTAL (SKC 226-15)
EXCESS									500	9	Excess
TO11	DG01009		1						1000	10	TOTAL
EXCESS									1000	11	Excess
Moisture			1						500	12	
Excess									5000	13	Excess
PUF	DG01010		1						35L		Port B

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/15/00											
EVENT 11											
AIRSENSE	DG01101	X									TOTAL
THC	DG01102	X									TOTAL
M-18	DG01103		1						25	1	TOTAL
M-18	DG01104			1					25	2	TOTAL
M-18 by MS	DG01105		1						25	3	TOTAL
M-18 by MS	DG01106			1					25	4	TOTAL
EXCESS									25	5	Excess
NIOSH 1500	DG01107		1						500	6	TOTAL Orbo 32L
EXCESS									500	7	Excess
NIOSH 2002	DG01108		1						500	8	TOTAL (SKC 226-15)
EXCESS									500	9	Excess
TO11	DG01109		1						1000	10	TOTAL
EXCESS									1000	11	Excess
Moisture			1						500	12	
Excess									5000	13	Excess
PUF	DG01110		1						35L		Port B

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/16/00											
EVENT 12											
AIRSENSE	DG01201	X									TOTAL
THC	DG01202	X									TOTAL
M-18	DG01203		1						25	1	TOTAL
M-18	DG01204			1					25	2	TOTAL
M-18 by MS	DG01205		1						25	3	TOTAL
M-18 by MS	DG01206			1					25	4	TOTAL
EXCESS									25	5	Excess
NIOSH 1500	DG01207		1						500	6	TOTAL Orbo 32L
EXCESS									500	7	Excess
NIOSH 2002	DG01208		1						500	8	TOTAL (SKC 226-15)
EXCESS									500	9	Excess
TO11	DG01209		1						1000	10	TOTAL
EXCESS									1000	11	Excess
Moisture			1						500	12	
Excess									5000	13	Excess
PUF	DG01210		1						35L		Port B

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
11/16/00											
EVENT 13											
AIRSENSE	DG01301	X									TOTAL
THC	DG01302	X									TOTAL
M-18	DG01303		1						25	1	TOTAL
M-18	DG01304			1					25	2	TOTAL
M-18 by MS	DG01305		1						25	3	TOTAL
M-18 by MS	DG01306			1					25	4	TOTAL
EXCESS									25	5	Excess
NIOSH 1500	DG01307		1						500	6	TOTAL Orbo 32L
EXCESS									500	7	Excess
NIOSH 2002	DG01308		1						500	8	TOTAL (SKC 226-15)
EXCESS									500	9	Excess
TO11	DG01309		1						1000	10	TOTAL
EXCESS									1000	11	Excess
Moisture			1						500	12	
Excess									5000	13	Excess
PUF	DG01310		1						35L		Port B
M-18	DG01311						X		25		BOTTLE - Mix 1A
M-18	DG01312						X		25		BOTTLE - Mix 1A
M-18	DG01313						X		25		TRAIN - Mix 1A
M-18	DG01314						X		25		TRAIN - Mix 1A
TO11	DG01315						X		500		BOTTLE - Mix 2
TO11	DG01316						X		500		BOTTLE - Mix 2
TO11	DG01317						X		500		TRAIN - Mix 2
TO11	DG01318						X		500		TRAIN - Mix 2

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/26/00											
EVENT 14											
AIRSENSE	DG01401										TOTAL
THC	DG01402	X									TOTAL
NIOSH 1500	DG01403		1						200	1	TOTAL - Orbo 32small
NIOSH 1500	DG01404		1						200	2	TOTAL - Orbo 32small
NIOSH 1500	DG01405		1						200	3	TOTAL - Orbo 32small
NIOSH 1500	DG01406		1						200	4	TOTAL - Orbo 32small
GAS,CO + CO2	DG01407		1						60	5	Bag sample to Airtoxics
NIOSH 1500	DG01408		1						200	6	TOTAL - Orbo 32small
NIOSH 1500	DG01409		1						200	7	TOTAL - Orbo 32small
NIOSH 1500	DG01410		1						200	8	TOTAL - Orbo 32small
NIOSH 1500	DG01411		1						200	9	TOTAL - Orbo 32small
NIOSH 1500	DG01412		1						200	10	TOTAL - Orbo 32small
NIOSH 1500	DG01413		1						200	11	TOTAL - Orbo 32small
Moisture			1						500	12	
Excess									5000	13	Excess
PUF	DG01414		1						35L		Port B

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/26/00											
EVENT 15											
AIRSENSE	DG01501										TOTAL
THC	DG01502	X									TOTAL
NIOSH 1500	DG01503		1						200	1	TOTAL - Orbo 32small
NIOSH 1500	DG01504		1						200	2	TOTAL - Orbo 32small
NIOSH 1500	DG01505		1						200	3	TOTAL - Orbo 32small
NIOSH 1500	DG01506		1						200	4	TOTAL - Orbo 32small
GAS,CO + CO2	DG01507		1						60	5	Bag sample to Airtoxics
NIOSH 1500	DG01508		1						200	6	TOTAL - Orbo 32small
NIOSH 1500	DG01509		1						200	7	TOTAL - Orbo 32small
NIOSH 1500	DG01510		1						200	8	TOTAL - Orbo 32small
NIOSH 1500	DG01511		1						200	9	TOTAL - Orbo 32small
NIOSH 1500	DG01512		1						200	10	TOTAL - Orbo 32small
NIOSH 1500	DG01513		1						200	11	TOTAL - Orbo 32small
Moisture			1						500	12	
Excess									5000	13	Excess
PUF	DG01514		1						35L		Port B

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/26/00											
EVENT 16											
AIRSENSE	DG01601										TOTAL
THC	DG01602	X									TOTAL
NIOSH 1500	DG01603		1						200	1	TOTAL - Orbo 32small
NIOSH 1500	DG01604		1						200	2	TOTAL - Orbo 32small
NIOSH 1500	DG01605		1						200	3	TOTAL - Orbo 32small
NIOSH 1500	DG01606		1						200	4	TOTAL - Orbo 32small
GAS,CO + CO2	DG01607		1						60	5	Bag sample to Airtoxics
NIOSH 1500	DG01608		1						200	6	TOTAL - Orbo 32small
NIOSH 1500	DG01609		1						200	7	TOTAL - Orbo 32small
NIOSH 1500	DG01610		1						200	8	TOTAL - Orbo 32small
NIOSH 1500	DG01611		1						200	9	TOTAL - Orbo 32small
NIOSH 1500	DG01612		1						200	10	TOTAL - Orbo 32small
NIOSH 1500	DG01613		1						200	11	TOTAL - Orbo 32small
Moisture			1						500	12	
Excess									5000	13	Excess
PUF	DG01614		1						35L		Port B

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/26/00											
EVENT 17											
AIRSENSE	DG01701										TOTAL
THC	DG01702	X									TOTAL
NIOSH 1500	DG01703		1						200	1	TOTAL - Orbo 32small
NIOSH 1500	DG01704		1						200	2	TOTAL - Orbo 32small
NIOSH 1500	DG01705		1						200	3	TOTAL - Orbo 32small
NIOSH 1500	DG01706		1						200	4	TOTAL - Orbo 32small
GAS,CO + CO2	DG01707		1						60	5	Bag sample to Airtoxics
NIOSH 1500	DG01708		1						200	6	TOTAL - Orbo 32small
NIOSH 1500	DG01709		1						200	7	TOTAL - Orbo 32small
NIOSH 1500	DG01710		1						200	8	TOTAL - Orbo 32small
NIOSH 1500	DG01711		1						200	9	TOTAL - Orbo 32small
NIOSH 1500	DG01712		1						200	10	TOTAL - Orbo 32small
NIOSH 1500	DG01713		1						200	11	TOTAL - Orbo 32small
Moisture			1						500	12	
Excess									5000	13	Excess
PUF	DG01714		1						35L		Port B

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/27/00											
EVENT 18											
AIRSENSE	DG01801										TOTAL
THC	DG01802	X									TOTAL
NIOSH 1500	DG01803		1						200	1	TOTAL - Orbo 32small
NIOSH 1500	DG01804		1						200	2	TOTAL - Orbo 32small
NIOSH 1500	DG01805		1						200	3	TOTAL - Orbo 32small
NIOSH 1500	DG01806		1						200	4	TOTAL - Orbo 32small
GAS,CO + CO2	DG01807		1						60	5	Bag sample to Airtoxics
NIOSH 1500	DG01808		1						200	6	TOTAL - Orbo 32small
NIOSH 1500	DG01809		1						200	7	TOTAL - Orbo 32small
NIOSH 1500	DG01810		1						200	8	TOTAL - Orbo 32small
NIOSH 1500	DG01811		1						200	9	TOTAL - Orbo 32small
NIOSH 1500	DG01812		1						200	10	TOTAL - Orbo 32small
NIOSH 1500	DG01813		1						200	11	TOTAL - Orbo 32small
Moisture			1						500	12	
Excess									5000	13	Excess
PUF	DG01814		1						35L		Port B

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/27/00											
EVENT 19											
AIRSENSE	DG01901										TOTAL
THC	DG01902	X									TOTAL
NIOSH 1500	DG01903		1						200	1	TOTAL - Orbo 32small
NIOSH 1500	DG01904		1						200	2	TOTAL - Orbo 32small
NIOSH 1500	DG01905		1						200	3	TOTAL - Orbo 32small
NIOSH 1500	DG01906		1						200	4	TOTAL - Orbo 32small
GAS,CO + CO2	DG01907		1						60	5	Bag sample to Airtoxics
NIOSH 1500	DG01908		1						200	6	TOTAL - Orbo 32small
NIOSH 1500	DG01909		1						200	7	TOTAL - Orbo 32small
NIOSH 1500	DG01910		1						200	8	TOTAL - Orbo 32small
NIOSH 1500	DG01911		1						200	9	TOTAL - Orbo 32small
NIOSH 1500	DG01912		1						200	10	TOTAL - Orbo 32small
NIOSH 1500	DG01913		1						200	11	TOTAL - Orbo 32small
Moisture			1						500	12	
Excess									5000	13	Excess
PUF	DG01914		1						35L		Port B

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/27/00											
EVENT 20											
AIRSENSE	DG02001										TOTAL
THC	DG02002	X									TOTAL
NIOSH 1500	DG02003		1						200	1	TOTAL - Orbo 32small
NIOSH 1500	DG02004		1						200	2	TOTAL - Orbo 32small
NIOSH 1500	DG02005		1						200	3	TOTAL - Orbo 32small
NIOSH 1500	DG02006		1						200	4	TOTAL - Orbo 32small
GAS,CO + CO2	DG02007		1						60	5	Bag sample to Airtoxics
NIOSH 1500	DG02008		1						200	6	TOTAL - Orbo 32small
NIOSH 1500	DG02009		1						200	7	TOTAL - Orbo 32small
NIOSH 1500	DG02010		1						200	8	TOTAL - Orbo 32small
NIOSH 1500	DG02011		1						200	9	TOTAL - Orbo 32small
NIOSH 1500	DG02012		1						200	10	TOTAL - Orbo 32small
NIOSH 1500	DG02013		1						200	11	TOTAL - Orbo 32small
Moisture			1						500	12	
Excess									5000	13	Excess
PUF	DG02014		1						35L		Port B

PRE-PRODUCTION DG SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
12/27/00											
EVENT 21											
AIRSENSE	DG02101										TOTAL
THC	DG02102	X									TOTAL
NIOSH 1500	DG02103		1						200	1	TOTAL - Orbo 32small
NIOSH 1500	DG02104		1						200	2	TOTAL - Orbo 32small
NIOSH 1500	DG02105		1						200	3	TOTAL - Orbo 32small
NIOSH 1500	DG02106		1						200	4	TOTAL - Orbo 32small
GAS,CO + CO2	DG02107		1						60	5	Bag sample to Airtoxics
NIOSH 1500	DG02108		1						200	6	TOTAL - Orbo 32small
NIOSH 1500	DG02109		1						200	7	TOTAL - Orbo 32small
NIOSH 1500	DG02110		1						200	8	TOTAL - Orbo 32small
NIOSH 1500	DG02111		1						200	9	TOTAL - Orbo 32small
NIOSH 1500	DG02112		1						200	10	TOTAL - Orbo 32small
NIOSH 1500	DG02113		1						200	11	TOTAL - Orbo 32small
Moisture			1						500	12	
Excess									5000	13	Excess
PUF	DG02114		1						35L		Port B

TECHNIKON TEST PLAN

- > **CONTRACT NUMBER:** 1256 **TASK NUMBER:** 110
- > **CONTROL NUMBER:** RE 1 00119
- > **SAMPLE FAMILY:** DX
- > **SAMPLE EVENTS:** 001 thru 007
- > **SITE:** __X__**PRE-PRODUCTION(243)**____**CERP FOUNDRY(238)**
- > **TEST TYPE**: Ashland Furan Fe No-Bake (NBF-1 Resin, NBF-4 Catalyst) Vendor Study
- > **MOLD TYPE:** Furan No-Bake Iron System
- > **NUMBER OF MOLDS:** 7
- > **CORE TYPE:** N/A
- > **TEST DATE:** **START:** 25 Jan 01

FINISH: 30 Jan 01

TEST OBJECTIVES:

Primary: To measure emissions from No-Bake molds, formulated for use with cast iron, and manufactured based on protocols developed in capability study CP, CW, and DJ. This test to be compared to Furan-Iron No-bake baseline DJ. The THC analyzer will be used to monitor the test and sample tubes will be collected for analysis by an outside laboratory.

VARIABLES: No-bake resin at 1.3% resin (BOS) with acid catalyst. The amount of catalyst to be determined in a pretest evaluation of strip time on 70-80^{o} F sand. Recommended value is 35% catalyst.

BRIEF OVERVIEW: The molds will be the standard 4-on variable-tooth gear made from Amador 70 sand with the above resin system. The molds will be transferred to the Pouring/cooling/shakeout hooded station used for greensand and core baselines.

Protocols were developed in CW and CP for making Phenolic Urethane no-bake molds. Furan is a different chemical system whose physical, mechanical, and emission characteristics may not fall within the parameters of the Phenolic Urethane test criteria. Criteria for this material were supplementally determined in capability study DJ.

SPECIAL CONDITIONS: The THC will be used to validate whether mold has cracked before shakeout.

Steven M Knight	23 Jan 01
Process Engineering Manager (Technikon)	**Date**
[signature]	1-23-01
V.P. Measurement Technology (Technikon)	**Date**
[signature]	1-23-01
V.P. Operations (Technikon)	**Date**
[signature]	5/31/01
Emissions Team (USCAR)	**Date**
[signature]	5/31/01
Process and Facilities Team (USCAR)	**Date**
R.O. Myers	6/1/01
Project Manager (CTC)	**Date**

Series DX

Pre-production Iron Furan No-bake Process Instructions

A. Experiment:

1. Establish an Iron No-Bake Furan Baseline to which other No-bake vendor materials will be compared.

B. Materials:

1. No-bake molds: Amador 70 and 1.3% Ashland No-bake Furan core resin composed of NBF-1 part I Furan resin, and NBF-4 Acid catalyst. These resins are designed for iron applications.
2. Metal: Class 30 Gray cast iron

Caution: Observe all safety precautions attendant to these operations as delineated in the Pre-production operating and safety instruction manual.

C. Catalyst requirements

1. The catalyst requirement for this system is not insignificant and must be recognized as one of the source material for emissions.
2. Before the scheduled test date conduct a strip time determination in the sand lab at the required resin content and operating temperature. Use the minimum catalyst so determined.

D. Mold requirements

1. Make nine (9) Furan no-bake molds according standards determined in CW, CP, DJ capability studies.
2. Make the molds with a 7 inch high drag and 7 inch high cope.
3. Monitor the pour with the THC to detect mold cracking before shakeout.

E. Furan No-bake Core Sand preparation:

1. The Furan no-bake sand shall be 1.3% total resin (BOS). The amount of catalyst shall be pre-determined in a strip time evaluation.
2. Use pump 1 for the resin and pump 2 for the catalyst.
3. Flush the part 1 and Part 2 pumps and lines with the Furan resin and acid catalysts respectively until only these materials come out. The part 3 pump is not used.
4. Calibrate the Kloster no-bake sand mixer to dispense 180 pounds/min more or less.

5. Calibrate the resin pumps:

   a) Furan resin Part I: Based on the actual measured sand dispensing rate calibrate the furan resin to be 1.3% resin +/- .01% (BOS).
   b) Acid catalyst Part II: Calibrate the acid catalyst pump per the strip time evaluation +/- .25% of the Furan resin (part I).

F. **Dog bones**:

1. Make 24 dogbones according to the protocol established in capability study CW. Two (2) 12-piece sets of test dogbones using 12-on core box)
2. Sample the raw uncoated sand from the hopper feeding the core sand mixer, bag, label with date, time, and mold number. Send to sand lab for LOI comparison.
3. Place the core box on the vibrating compaction table.
4. Start the Kloster mixer and waste a few pounds of sand.
5. Flood the core box with sand then stop the mixer.
6. Strike off the core box to ½ inch deep
7. Turn on the vibrating compaction table for 15 seconds.
8. Screed off most of the excess sand.
9. Screed the core box a second time moving very slowly in a back and forth manner to remove **all** excess sand.

Note: It is important to neither gouge the sand nor leave excess sand in center neck portion of the dogbone or the test results will be affected

10. Set aside for a time equivalent to the pre-determined strip time or until hard to the touch.
11. Carefully remove the cores from the core box by separating the corebox components.
12. Place 6 bones in the 90% Rh cabinet.
13. Perform tensile tests on 6 bones at each of the following times after dogbone manufacture: 30 minutes, 2 hours, 24 hours, and 24 hours@ 90 % Rh. Report the average and standard deviation for each set of six (6) at each time for each mold.
14. Weigh each dogbone and record the weight to the nearest 0.1 grams using the PJ 4000 electronic scale at the time it is tensile tested.

Note: maintain the correlation between the reported weight of a dogbone and its tensile strength and scratch hardness.

15. Run a 1400^{o} F core LOI on three (3) of the 30- minute tensile test dogbones. Report the average value for each mold.
16. Run a 1400^{o} F core LOI on the raw uncoated sand sampled at the same time as the dogbones are made. Calculate a Core Resin LOI as the difference between the average Core LOI and raw sand core LOI. Report this value for each mold.

G. **No-bake mold making: 4 on gear core box.**

1. Inspect the box for cracks and other damage. Repair before use.
2. Prepare the core box halves with a light coating of Ashland Zipslip® IP 78. Allow to fully dry.
3. Place the drag core box on the vibrating compaction table.
4. Begin filling the box.
5. Immediately start the table vibration.
6. Manually spread the sand around the box as it is filling.
7. Strike off the box until it is full.
8. Allow the vibrator to run an additional 10 seconds after the box is full.
9. Strike off the core box so that the core mold is 7 inches thick.
10. Set the core box aside for 5 to 6 minutes or until it is hard to the touch.
11. Invert the box and place on a transport pallet.
12. Remove the pivot hole pins.
13. Remove the core mold half by tapping lightly on the box with a soft hammer.
14. Set the drag core box aside.
15. Place the cope core box on the vibrating compaction table.
16. Follow steps F3-F13 except that the cope mold is 7 inches thick.
17. Rotate the unboxed core to set it on edge.
18. Drill vent holes as per template.
19. Hand trim the pour basin to promote minimum splash and minimum cup volume.
20. Close cope onto drag. Visually check for closure.
21. Install two (2) steel straps, one on either side of the pouring cup, with 4 metal corner protectors each to hold the mold tightly closed.
22. Weigh and record the weight of the closed mold.

H. Emission hood:

1. Loading.

   a) Hoist the mold onto the shakeout deck fixture within the emission hood with the pouring cup side toward the furnace.
   b) Install the cope weighting device.
   c) Install a half inch re-rod casting hangers through the cope into each of the four riser cavities and suspend them over the horizontal mold retaining bars.
   d) Close, seal, and lock the emission hood

2. Shakeout.

   a) After 45 minutes of cooling time has elapsed turn on the shakeout unit and run for 15 minutes as prescribed in the emission test plan. from pouring.
   b) Turn off the shakeout. The emission sampling will continue for an additional 15 minutes or a total of 75 minutes
   c) Wait for the emission team to signal that they are finished sampling.
   d) Open the hood, remove the castings
   e) Clean core sand out of the pit and off the shakeout.
   f) Weigh and record cast metal weight.

I. Melting:

1. Initial charge:

a) Charge the furnace according to the **Generic Start Up Charge for Pre-production** heat recipe bearing effectivity date 18 Mar 1999.
b) Place part of the steel scrap on the bottom, followed by carbon alloys, and the balance of the steel.
c) Place a pig on top on top.
d) Bring the furnace contents to the point of beginning to melt over a period of 1 hour at reduced power.
e) Add the balance of the metallics under full power until all is melted and the temperature has reached 2600 to 2700^{o} F.
f) Slag the furnace and add the balance of the alloys.
g) Raise the temperature of the melt to 2700^{o} F and take a DataCast 2000 sample. The temperature of the primary liquidus (TPL) must be in the range of 2200-2350^{o} F.
h) Hold the furnace at 2500-2550^{o} F until near ready to tap.
i) When ready to tap raise the temperature to 2700^{o} F and slag the furnace.
j) Record all metallic and alloy additions to the furnace, tap temperature, and pour temperature. Record all furnace activities with an associated time.

2. Back charging.

a) If additional iron is desired back charge according to the **Generic Pre-production Last Melt** heat recipe bearing effectivity date 18 Mar 1999.
b) Charge a few pieces of steel first to make a splash barrier, followed by the carbon alloys.
c) Follow the above steps beginning with H.1.e

3. Emptying the furnace.

a) Pig the extra metal only after the last emission measurement is complete to avoid contaminating the air sample.
b) Cover the empty furnace with ceramic blanket to cool.

J. Pouring:

1. Preheat the ladle.

a) Tap 400 pounds more or less of 2700^{o} F metal into the cold ladle.
b) Casually pour the metal back to the furnace.
c) Cover the ladle.
d) Reheat the metal to 2780 +/- 20^{o} F.

e) Tap 450 pounds more or less of iron into the ladle while pouring inoculating alloys onto the metal stream near its base.
f) Cover the ladle to conserve heat.
g) Move the ladle to the pour position, open the emission hood pour door and wait until the metal temperature reaches 2630 +/- 10^{o} F.
h) Commence pouring keeping the sprue full.
i) Upon completion close the hood door, return the extra metal to the furnace, and cover the ladle.

Steven Knight
Manager, Process Engineering

PRE-PRODUCTION DX SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/25/01											Samples to Clayton Lab.
EVENT 1											unless noted.
AIRSENSE	DX00101										TOTAL
THC	DX00102	X									TOTAL
M-18	DX00103		1						25	1	TOTAL
M-18	DX00104			1					25	2	TOTAL
M-18	DX00105				1				0	2	QC-Manifold Blank
M-18 MS (Quant)	DX00106		1						25	3	TOTAL
M-18 MS (Quant)	DX00107			1					25	4	TOTAL
M-18 MS (Quant)	DX00108				1				0	4	QC-Manifold Blank
GAS,CO + CO2	DX00109		1						60	5	TEDLAR BAG Sample to Air-toxics Lab.
NIOSH 2505	DX00110		1						1000	6	TOTAL (SKC 226-115)
NIOSH 2505	DX00111				1				0	6	QC - Manifold Blank
Excess									1000	7	Excess
TO11	DX00112		1						750	8	Total
TO11	DX00113				1				0	8	QC - Manifold Blank
NIOSH 1500	DX00114		1						500	9	TOTAL (Orbo 32L)
NIOSH 1500	DX00115				1				0	9	QC - Manifold Blank, (Orbo 32L)
NIOSH 2002	DX00116		1						750	10	TOTAL (SKC 226-15)
NIOSH 2002	DX00117				1				0	10	QC- Manifold Blank (SKC 226-15)
OSHA 72	DX00118		1						1700	11	TOTAL (SKC 226-38)
OSHA 72	DX00119					1			1700	11	TOTAL (SKC 226-38)
OSHA 72	DX00120				1				0	11	QC - Manifold Blank
Moisture									500	12	EPA Method 4
Excess									2500	13	
PUF	DX001		1						15L		Sample using opposite port

PRE-PRODUCTION DX SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/25./2001											Samples to Clayton Lab.
EVENT 2											unless noted.
AIRSENSE	DX00201										TOTAL
THC	DX00202	X									TOTAL
M-18	DX00203		1						25	1	TOTAL
M-18	DX00204					1			25	1	TOTAL
M-18	DX00205			1					25	2	TOTAL
M-18	DX00206					1			25	2	TOTAL
M-18 MS (Quant)	DX00207		1						25	3	TOTAL
M-18 MS (Quant)	DX00208					1			25	3	TOTAL
M-18 MS (Quant)	DX00209			1					25	4	TOTAL
M-18 MS (Quant)	DX00210					1			25	4	TOTAL
GAS,CO + CO2	DX00211		1						60	5	TEDLAR BAG Sample to Air-toxics Lab.
NIOSH 2505	DX00212		1						1000	6	TOTAL (SKC 226-115)
Excess									1000	7	Excess
TO11	DX00213		1						750	8	Total
TO11	DX00214					1			750	8	Total
NIOSH 1500	DX00215		1						500	9	TOTAL (Orbo 32L)
NIOSH 2002	DX00216		1						750	10	TOTAL (SKC 226-15)
OSHA 72	DX00217		1						1700	11	TOTAL (SKC 226-38)
OSHA 72	DX00218					1			1700	11	TOTAL (SKC 226-38)
Moisture									500	12	EPA Method 4
Excess									2500	13	
PUF	DX002		1						15L		Sample using opposite port

PRE-PRODUCTION DX SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/25/01											Samples to Clayton Lab.
EVENT 3											unless noted.
AIRSENSE	DX00301										TOTAL
THC	DX00302	X									TOTAL
M-18	DX00303		1						25	1	TOTAL
M-18	DX00304			1					25	2	TOTAL
M-18 MS (Quant)	DX00305		1						25	3	TOTAL
M-18 MS (Quant)	DX00306			1					25	4	TOTAL
GAS,CO + CO2	DX00307		1						60	5	TEDLAR BAG Sample to Airtoxics Lab.
NIOSH 2505	DX00308		1						1000	6	TOTAL (SKC 226-115)
NIOSH 2505	DX00309			1					1000	7	TOTAL (SKC 226-115)
TO11	DX00310		1						750	8	Total
NIOSH 1500	DX00311		1						500	9	TOTAL (Orbo 32L)
NIOSH 2002	DX00312		1						750	10	TOTAL (SKC 226-15)
OSHA 72	DX00313		1						1700	11	TOTAL (SKC 226-38)
OSHA 72	DX00314					1			1700	11	TOTAL (SKC 226-38)
Moisture									500	12	EPA Method 4
Excess									2500	13	
PUF	DX003		1						15L		Sample using opposite port

PRE-PRODUCTION DX SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/29/01											Samples to Clayton Lab.
EVENT 4											unless noted.
AIRSENSE	DX00401										TOTAL
THC	DX00402	X									TOTAL
M-18	DX00403		1						25	1	TOTAL
M-18	DX00404			1					25	2	TOTAL
M-18 MS (Quant)	DX00405		1						25	3	TOTAL
M-18 MS (Quant)	DX00406			1					25	4	TOTAL
GAS,CO + CO2	DX00407		1						60	5	TEDLAR BAG Sample to Airtoxics Lab.
NIOSH 2505	DX00408		1						1000	6	TOTAL (SKC 226-115)
Excess									1000	7	Excess
TO11	DX00409		1						750	8	Total
NIOSH 1500	DX00410		1						500	9	TOTAL (Orbo 32L)
NIOSH 2002	DX00411		1						750	10	TOTAL (SKC 226-15)
OSHA 72	DX00412		1						1700	11	TOTAL (SKC 226-38)
OSHA 72	DX00413					1			1700	11	TOTAL (SKC 226-38)
Moisture									500	12	EPA Method 4
Excess									2500	13	
PUF	DX004		1						15L		Sample using opposite port

PRE-PRODUCTION DX SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/29/01											Samples to Clayton Lab.
EVENT 5											unless noted.
AIRSENSE	DX00501										TOTAL
THC	DX00502	X									TOTAL
M-18	DX00503		1						25	1	TOTAL
M-18	DX00504			1					25	2	TOTAL
M-18 MS (Quant)	DX00505		1						25	3	TOTAL
M-18 MS (Quant)	DX00506			1					25	4	TOTAL
GAS,CO + CO2	DX00507		1						60	5	TEDLAR BAG Sample to Airtoxics Lab.
NIOSH 2505	DX00508		1						1000	6	TOTAL (SKC 226-115)
Excess									1000	7	Excess
TO11	DX00509		1						750	8	Total
NIOSH 1500	DX00510		1						500	9	TOTAL (Orbo 32L)
NIOSH 2002	DX00511		1						750	10	TOTAL (SKC 226-15)
OSHA 72	DX00512		1						1700	11	TOTAL (SKC 226-38)
OSHA 72	DX00513					1			1700	11	TOTAL (SKC 226-38)
Moisture									500	12	EPA Method 4
Excess									2500	13	
PUF	DX005		1						15L		Sample using opposite port

PRE-PRODUCTION DX SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/29/01											Samples to Clayton Lab.
EVENT 6											unless noted.
AIRSENSE	DX00601										TOTAL
THC	DX00602	X									TOTAL
M-18	DX00603		1						25	1	TOTAL
M-18	DX00604			1					25	2	TOTAL
M-18 MS (Quant)	DX00605		1						25	3	TOTAL
M-18 MS (Quant)	DX00606			1					25	4	TOTAL
GAS,CO + CO2	DX00607		1						60	5	TEDLAR BAG Sample to Airtoxics Lab.
NIOSH 2505	DX00608		1						1000	6	TOTAL (SKC 226-115)
Excess									1000	7	Excess
TO11	DX00609		1						750	8	Total
NIOSH 1500	DX00610		1						500	9	TOTAL (Orbo 32L)
NIOSH 2002	DX00611		1						750	10	TOTAL (SKC 226-15)
OSHA 72	DX00612		1						1700	11	TOTAL (SKC 226-38)
OSHA 72	DX00613					1			1700	11	TOTAL (SKC 226-38)
Moisture									500	12	EPA Method 4
Excess									2500	13	
PUF	DX006		1						15L		Sample using opposite port

PRE-PRODUCTION DX SERIES SAMPLE PLAN

Method	Sample #	Data	Sample	Duplicate	Blank	Breakthrough	Spike	Spike Duplicate	Flow (ml/min)	Train Channel	Comments
1/30/01											Samples to Clayton Lab.
EVENT 7											unless noted.
AIRSENSE	DX00701										TOTAL
THC	DX00702	X									TOTAL
M-18	DX00703		1						25	1	TOTAL
M-18	DX00704			1					25	2	TOTAL
M-18 MS (Quant)	DX00705		1						25	3	TOTAL
M-18 MS (Quant)	DX00706			1					25	4	TOTAL
GAS,CO + CO2	DX00707		1						60	5	TEDLAR BAG Sample to Airtoxics Lab.
NIOSH 2505	DX00708		1						1000	6	TOTAL (SKC 226-115)
NIOSH 2505	DX00709			1					1000	7	TOTAL (SKC 226-115)
TO11	DX00710		1						750	8	Total
NIOSH 1500	DX00711		1						500	9	TOTAL (Orbo 32L)
NIOSH 2002	DX00712		1						750	10	TOTAL (SKC 226-15)
OSHA 72	DX00713		1						1700	11	TOTAL (SKC 226-38)
OSHA 72	DX00714					1			1700	11	TOTAL (SKC 226-38)
Moisture									500	12	EPA Method 4
Excess									2500	13	
PUF	DX007		1						15L		Sample using opposite port
M-18	DX00715						X				BOTTLE-MIX 1A
M-18	DX00716						X				BOTTLE-MIX 1A
TO-11	DX00717						X				BOTTLE -MIX 2
TO-11	DX00718						X				BOTTLE -MIX 2

APPENDIX B TEST SERIES DG AND DX DETAILED RESULTS

Test Plan DG and DX Average Test Results with T-Statistics

Analytes	Test DG (Lb/Tn)	Test DX (Lb/Tn)	T-Statistic
TGOC (THC) as Propane	12.2	2.62	32.9
HC as Hexane	11.1	1.72	31.7
Sum of VOCs	4.06	1.10	15.6
Sum of HAPs	2.00	1.08	11.4
Sum of POMs	0.104	0.006	14.6
Individual Organic HAPs			
Phenol	0.942	0.044	19.2
o,m,p-Cresol	0.500	ND	18.0
Benzene	0.299	0.818	21.2
Dimethylnaphthalenes	0.086	ND	15.2
Toluene	0.056	0.106	13.0
Formaldehyde	0.021	0.025	1.42
Acetaldehyde	0.004	0.066	13.3
Other VOCs			
Dimethylphenols	1.07	ND	24.4
Diethylbenzenes	0.299	ND	4.05
Trimethylbenzenes	0.216	ND	12.1
Tetradecane	0.141	ND	11.3
Butylbenzenes	0.116	ND	8.38
Dodecane	0.060	ND	21.0
Indan	0.057	ND	28.9
Undecane	0.033	ND	21.7
Other Analytes			
Condensables	0.800	2.28	9.35
Carbon Monoxide	4.18	5.99	8.85
Methane	0.590	0.352	9.43
Carbon Dioxide	59.3	47.1	3.46

Individual results shown constitute >95% of mass of all detected VOCs.

Test Plan DG Individual Test Results – Lbs/Tn Metal

POMs	HAPS	COMPOUND / SAMPLE NUMBER	DG005	DG006	DG007	DG008	DG009	DG010	DG011	DG012	DG013	AVERAGE	STDEV
		Pour Date	**11/14/00**	**11/14/00**	**11/14/00**	**11/15/00**	**11/15/00**	**11/15/00**	**11/15/00**	**11/16/00**	**11/16/00**		
		THC as Propane	1.25E+01	1.09E+01	1.35E+01	1.26E+01	1.23E+01	1.23E+01	1.17E+01	I	1.15E+01	1.22E+01	7.85E-01
		HC as Hexane	1.06E+01	9.92E+00	1.27E+01	1.16E+01	1.10E+01	1.14E+01	1.10E+01	I	1.07E+01	1.11E+01	8.21E-01
		Sum of VOCs	4.08E+00	3.95E+00	4.83E+00	3.33E+00	4.40E+00	4.62E+00	3.49E+00	I	3.80E+00	4.06E+00	5.28E-01
		Sum of HAPs	1.80E+00	2.01E+00	2.28E+00	1.72E+00	2.28E+00	2.10E+00	1.93E+00	I	1.88E+00	2.00E+00	2.09E-01
		Sum of POMs	1.11E-01	9.14E-02	1.13E-01	8.12E-02	1.24E-01	1.31E-01	8.32E-02	I	9.43E-02	1.04E-01	1.89E-02
			Individual HAPs and VOCs										
	z	Phenol	7.56E-01	1.01E+00	1.10E+00	8.32E-01	1.13E+00	9.46E-01	9.39E-01	I	8.34E-01	9.42E-01	1.32E-01
	z	m,p-Cresol	4.53E-01	4.10E-01	5.25E-01	3.47E-01	4.97E-01	5.10E-01	4.17E-01	I	4.78E-01	4.55E-01	6.02E-02
	z	Benzene	2.85E-01	2.86E-01	2.71E-01	3.10E-01	3.10E-01	3.18E-01	3.14E-01	I	2.94E-01	2.99E-01	1.68E-02
	z	Toluene	5.12E-02	5.02E-02	6.53E-02	5.33E-02	5.65E-02	5.78E-02	5.84E-02	I	5.17E-02	5.56E-02	5.02E-03
x	z	1,2-Dimethylnaphthalene	4.80E-02	4.35E-02	4.80E-02	3.85E-02	5.31E-02	5.57E-02	3.75E-02	I	4.23E-02	4.58E-02	6.55E-03
	z	o-Cresol	3.56E-02	6.83E-02	8.54E-02	1.31E-02	5.46E-02	6.11E-02	2.74E-02	I	2.05E-02	4.58E-02	2.55E-02
	z	m,p-Xylene	2.27E-02	2.20E-02	2.77E-02	2.14E-02	2.31E-02	2.55E-02	2.33E-02	I	2.13E-02	2.34E-02	2.20E-03
	z	Formaldehyde	3.17E-02	2.03E-02	2.47E-02	1.37E-02	2.65E-02	9.42E-03	9.66E-03	I	2.83E-02	2.05E-02	8.67E-03
x	z	1,5-Dimethylnaphthalene	1.98E-02	1.66E-02	2.05E-02	1.34E-02	2.22E-02	2.42E-02	1.52E-02	I	1.62E-02	1.85E-02	3.72E-03
	z	Aniline	1.57E-02	1.94E-02	2.46E-02	1.57E-02	1.64E-02	I	1.88E-02	I	1.89E-02	1.85E-02	3.13E-03
	z	Styrene	1.40E-02	1.38E-02	1.58E-02	1.26E-02	1.48E-02	1.52E-02	1.47E-02	I	1.32E-02	1.43E-02	1.05E-03
x	z	1,3-Dimethylnaphthalene	1.41E-02	1.26E-02	1.46E-02	1.04E-02	1.63E-02	1.69E-02	1.07E-02	I	1.20E-02	1.35E-02	2.45E-03
x	z	2-Methylnaphthalene	1.25E-02	1.10E-02	1.26E-02	9.23E-03	1.40E-02	1.39E-02	9.27E-03	I	1.06E-02	1.16E-02	1.90E-03
	z	o-Xylene	7.78E-03	7.42E-03	9.23E-03	7.41E-03	8.12E-03	8.75E-03	8.07E-03	I	7.42E-03	8.03E-03	6.71E-04
x	z	1-Methylnaphthalene	6.69E-03	5.84E-03	6.94E-03	5.13E-03	7.90E-03	8.06E-03	5.28E-03	I	5.85E-03	6.46E-03	1.12E-03
	z	Ethyl benzene	5.76E-03	5.97E-03	5.87E-03	5.03E-03	6.78E-03	7.40E-03	6.46E-03	I	5.33E-03	6.07E-03	7.76E-04
x	z	1,6-Dimethylnaphthalene	6.37E-03	ND	7.00E-03	4.48E-03	7.12E-03	8.10E-03	5.20E-03	I	5.34E-03	5.45E-03	2.50E-03
	z	Biphenyl	4.88E-03	4.01E-03	4.78E-03	3.53E-03	5.17E-03	5.31E-03	3.53E-03	I	3.95E-03	4.40E-03	7.23E-04
	z	Acetaldehyde	I	3.84E-03	3.27E-03	3.68E-03	6.77E-03	2.89E-03	2.70E-03	I	5.38E-03	4.08E-03	1.48E-03

Test Plan DG Individual Test Results – Lbs/Tn Metal

POMs	HAPS	COMPOUND / SAMPLE NUMBER	DG005	DG006	DG007	DG008	DG009	DG010	DG011	DG012	DG013	AVERAGE	STDEV
		Pour Date	**11/14/00**	**11/14/00**	**11/14/00**	**11/15/00**	**11/15/00**	**11/15/00**	**11/15/00**	**11/16/00**	**11/16/00**		
x	z	2,3-Dimethylnaphthalene	3.22E-03	1.80E-03	3.63E-03	ND	3.82E-03	4.28E-03	ND	I	1.88E-03	2.33E-03	1.68E-03
	z	Acrolein	1.12E-03	8.85E-04	1.38E-03	7.09E-04	1.08E-03	3.94E-04	5.56E-04	I	1.28E-03	9.25E-04	3.51E-04
	z	Propionaldehyde	I	7.83E-04	8.34E-04	6.44E-04	1.01E-03	5.11E-04	4.95E-04	I	8.80E-04	7.37E-04	1.93E-04
	z	2-Butanone	ND	1.82E-04	6.86E-04	5.93E-04	ND	9.42E-04	I	I	ND	3.43E-04	3.91E-04
	z	Hexane	2.35E-03	ND	ND	ND	ND	ND	ND	I	ND	2.93E-04	8.30E-04
x	z	1,8-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
x	z	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
x	z	2,6-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
x	z	2,7-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
	z	Cumene	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
x	z	Naphthalene	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
	z	N,N-Dimethylaniline	I	I	I	I	I	I	I	I	I	N/A	N/A
		2,6-Dimethylphenol	1.11E+00	1.01E+00	1.28E+00	9.58E-01	1.13E+00	1.15E+00	9.20E-01	I	9.66E-01	1.07E+00	1.24E-01
		1,2-Diethylbenzene	4.40E-01	2.36E-01	5.65E-01	7.77E-03	2.60E-01	5.24E-01	7.68E-03	I	2.57E-01	2.87E-01	2.13E-01
		1,2,3-Trimethylbenzene	1.51E-01	1.39E-01	1.69E-01	1.30E-01	1.51E-01	1.46E-01	1.24E-01	I	1.26E-01	1.42E-01	1.52E-02
		Tetradecane	9.51E-02	1.72E-01	1.86E-01	1.53E-01	1.03E-01	1.05E-01	1.44E-01	I	1.67E-01	1.41E-01	3.52E-02
		Isobutyl benzene	1.44E-01	1.31E-01	6.73E-02	6.48E-02	1.52E-01	1.52E-01	1.32E-01	I	7.68E-02	1.15E-01	3.85E-02
		Dodecane	5.72E-02	5.09E-02	6.27E-02	5.29E-02	7.02E-02	7.22E-02	5.32E-02	I	5.78E-02	5.96E-02	8.01E-03
		Indan	5.68E-02	5.35E-02	6.73E-02	5.28E-02	5.87E-02	6.10E-02	5.24E-02	I	5.07E-02	5.67E-02	5.55E-03
		1,2,4-Trimethylbenzene	4.02E-02	3.75E-02	4.64E-02	3.67E-02	4.57E-02	4.68E-02	4.08E-02	I	4.04E-02	4.18E-02	4.00E-03
		Undecane	3.38E-02	2.82E-02	3.83E-02	2.95E-02	3.46E-02	4.04E-02	3.00E-02	I	3.13E-02	3.33E-02	4.34E-03
		1,3,5-Trimethylbenzene	5.51E-02	ND	ND	2.55E-02	ND	1.32E-01	ND	I	4.51E-02	3.23E-02	4.61E-02
		Indene	3.84E-02	3.60E-02	2.07E-02	1.24E-02	3.89E-02	2.17E-02	2.76E-02	I	2.62E-02	2.77E-02	9.49E-03
		Butyraldehyde/Methacrolien	3.14E-02	2.21E-02	I	1.82E-02	1.93E-02	1.74E-02	1.38E-02	I	2.62E-02	2.12E-02	5.94E-03
		1,3-Diethylbenzene	ND	ND	1.35E-02	4.64E-02	ND	1.34E-02	ND	I	2.15E-02	1.19E-02	1.63E-02

Test Plan DG Individual Test Results – Lbs/Tn Metal

POMs	HAPS	COMPOUND / SAMPLE NUMBER	DG005	DG006	DG007	DG008	DG009	DG010	DG011	DG012	DG013	AVERAGE	STDEV
		Pour Date	**11/14/00**	**11/14/00**	**11/14/00**	**11/15/00**	**11/15/00**	**11/15/00**	**11/15/00**	**11/16/00**	**11/16/00**		
		1,3-Diisopropylbenzene	9.80E-03	4.29E-03	9.29E-03	8.11E-03	9.21E-03	9.49E-03	8.42E-03	I	8.10E-03	8.34E-03	1.76E-03
		Tridecane	6.87E-03	7.66E-03	6.97E-03	5.53E-03	8.30E-03	7.95E-03	5.37E-03	I	6.27E-03	6.86E-03	1.09E-03
		2-Ethyltoluene	3.61E-03	5.13E-03	9.52E-03	3.12E-03	1.07E-02	6.65E-03	4.01E-03	I	5.78E-03	6.06E-03	2.76E-03
		Benzaldehyde	5.63E-03	4.09E-03	5.84E-03	2.99E-03	4.62E-03	2.66E-03	2.52E-03	I	5.42E-03	4.22E-03	1.37E-03
		o,m,p-Tolualdehyde	4.16E-03	2.96E-03	3.42E-03	1.96E-03	3.46E-03	1.71E-03	1.62E-03	I	3.65E-03	2.87E-03	9.75E-04
		Decane	ND	ND	ND	ND	1.11E-02	ND	ND	I	ND	1.38E-03	3.91E-03
		sec-Butylbenzene	ND	ND	ND	ND	3.02E-03	2.93E-03	ND	I	1.49E-03	9.30E-04	1.36E-03
		Pentanal	ND	ND	7.92E-04	ND	3.28E-03	2.75E-04	ND	I	ND	5.44E-04	1.14E-03
		2,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		1,4-Diethylbenzene	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		2,3,5-Trimethylphenol	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		2,3-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		2,4,6-Trimethylphenol	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		2,5-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		3,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		3,5-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		3-Ethyltoluene	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		4-Ethyltoluene	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
x		Ace naphthalene	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		a-Methyl styrene	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		Anthracene	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		Butylbenzene	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		Crotonaldehyde	ND	ND	ND	ND	ND	ND	I	I	ND	N/A	N/A
		Cyclohexane	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		Heptane	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A

Test Plan DG Individual Test Results – Lbs/Tn Metal

POMs	HAPS	COMPOUND / SAMPLE NUMBER	DG005	DG006	DG007	DG008	DG009	DG010	DG011	DG012	DG013	AVERAGE	STDEV
		Pour Date	**11/14/00**	**11/14/00**	**11/14/00**	**11/15/00**	**11/15/00**	**11/15/00**	**11/15/00**	**11/16/00**	**11/16/00**		
		Hexaldehyde	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		Nonane	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		n-Propylbenzene	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		Octane	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		p-Cymene	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
		tert-Butylbenzene	ND	ND	ND	ND	ND	ND	ND	I	ND	N/A	N/A
			Other Analytes										
		Acetone	I	1.24E-03	5.64E-04	1.72E-03	1.77E-03	1.70E-03	1.52E-03	I	1.45E-03	1.42E-03	4.21E-04
		Condensables	NT	8.85E-01	I	7.87E-01	8.08E-01	9.10E-01	6.73E-01	7.12E-01	8.26E-01	8.00E-01	8.56E-02

Test Plan DX Individual Test Results – Lbs/Tn Metal

HAPS	COMPOUND / SAMPLE NUMBER	DX001	DX002	DX003	DX004	DX005	DX006	DX007	AVERAGE	STDEV
	Pour Date	**1/25/01**	**1/25/01**	**1/25/01**	**1/29/01**	**1/29/01**	**1/29/01**	**1/30/01**		
	TGOC (THC) as Propane	2.49E+00	3.02E+00	2.72E+00	2.60E+00	2.70E+00	2.39E+00	2.44E+00	2.62E+00	2.14E-01
	HC as Hexane	1.64E+00	2.03E+00	1.75E+00	1.69E+00	1.80E+00	1.58E+00	1.57E+00	1.72E+00	1.58E-01
	Sum of VOCs	1.03E+00	1.27E+00	1.16E+00	1.09E+00	1.12E+00	1.02E+00	1.04E+00	1.10E+00	8.82E-02
	Sum of HAPs	1.01E+00	1.24E+00	1.14E+00	1.07E+00	1.10E+00	9.97E-01	1.02E+00	1.08E+00	8.62E-02
	Sum of POMs	2.85E-03	6.14E-03	7.93E-03	6.35E-03	6.67E-03	6.50E-03	6.75E-03	6.17E-03	1.57E-03
		Individual HAPs and VOCs								
Z	Benzene	7.77E-01	9.39E-01	8.51E-01	7.95E-01	8.29E-01	7.53E-01	7.82E-01	8.18E-01	6.28E-02
Z	Toluene	9.70E-02	1.19E-01	1.11E-01	1.03E-01	1.13E-01	9.53E-02	1.01E-01	1.06E-01	9.05E-03
Z	Acetaldehyde	5.40E-02	8.50E-02	7.27E-02	7.62E-02	6.43E-02	5.63E-02	5.40E-02	6.61E-02	1.22E-02
Z	Phenol	3.80E-02	4.96E-02	4.81E-02	4.56E-02	4.46E-02	4.44E-02	3.69E-02	4.39E-02	4.79E-03
Z	Formaldehyde	2.58E-02	2.31E-02	2.77E-02	3.00E-02	2.35E-02	2.52E-02	2.10E-02	2.52E-02	3.02E-03
Z	m,p-Xylene	6.63E-03	8.42E-03	8.47E-03	7.69E-03	8.30E-03	7.18E-03	7.82E-03	7.79E-03	6.92E-04
Z	Biphenyl	3.50E-03	4.76E-03	4.89E-03	4.32E-03	4.19E-03	4.45E-03	4.35E-03	4.35E-03	4.50E-04
Z	Naphthalene	2.85E-03	4.07E-03	4.32E-03	3.11E-03	3.49E-03	3.25E-03	3.18E-03	3.47E-03	5.39E-04
Z	2-Methylnaphthalene	ND	2.06E-03	3.61E-03	3.24E-03	3.18E-03	3.24E-03	3.57E-03	2.70E-03	1.30E-03
Z	2-Butanone	2.59E-03	I	2.63E-03	2.38E-03	3.20E-03	2.09E-03	2.97E-03	2.64E-03	3.98E-04
Z	Ethylbenzene	1.49E-03	1.85E-03	1.90E-03	1.69E-03	1.88E-03	1.57E-03	1.65E-03	1.72E-03	1.60E-04
Z	Propionaldehyde	8.61E-04	1.25E-03	1.40E-03	I	1.36E-03	1.03E-03	1.03E-03	1.16E-03	2.15E-04
Z	1,2-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
Z	1,3-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
Z	1,5-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
Z	1,6-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
Z	1,8-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
Z	1-Methylnaphthalene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
Z	2,3,5-Trimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A

Test Plan DX Individual Test Results – Lbs/Tn Metal

HAPS	COMPOUND / SAMPLE NUMBER	DX001	DX002	DX003	DX004	DX005	DX006	DX007	AVERAGE	STDEV
	Pour Date	1/25/01	1/25/01	1/25/01	1/29/01	1/29/01	1/29/01	1/30/01		
Z	2,3-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
Z	2,6-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
Z	2,7-Dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
Z	Acrolein	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
Z	Aniline	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
Z	Cumene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
Z	Hexane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
Z	m,p-Cresol	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
Z	N,N-Dimethylaniline	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
Z	o-Cresol	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
Z	o-Xylene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
Z	Styrene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	o,m,p-Tolualdehyde	9.92E-03	1.08E-02	1.04E-02	I	9.99E-03	9.38E-03	9.57E-03	1.00E-02	5.25E-04
	Benzaldehyde	5.86E-03	7.98E-03	7.26E-03	7.55E-03	6.54E-03	6.17E-03	6.28E-03	6.81E-03	7.94E-04
	Furfural	2.64E-03	3.34E-03	3.21E-03	3.20E-03	3.01E-03	2.11E-03	2.07E-03	2.80E-03	5.35E-04
	Pentanal	1.71E-03	2.50E-03	2.41E-03	2.49E-03	1.79E-03	1.89E-03	1.92E-03	2.10E-03	3.49E-04
	Hexaldehyde	1.16E-03	1.92E-03	I	1.27E-03	1.58E-03	9.88E-04	1.71E-03	1.44E-03	3.56E-04
	Butyraldehyde/Methacrolien	8.01E-04	I	1.06E-03	9.69E-04	8.97E-04	7.66E-04	8.61E-04	8.93E-04	1.10E-04
	Crotonaldehyde	3.61E-04	4.46E-04	4.80E-04	4.84E-04	3.51E-04	3.38E-04	3.40E-04	4.00E-04	6.71E-05
	Furfuryl Alcohol	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	1,2,3-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	1,2,4-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	1,2-Diethylbenzene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	1,3,5-Trimethylbenzene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	1,3-Diethylbenzene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	1,3-Diisopropylbenzene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A

Test Plan DX Individual Test Results – Lbs/Tn Metal

HAPS	COMPOUND / SAMPLE NUMBER	DX001	DX002	DX003	DX004	DX005	DX006	DX007	AVERAGE	STDEV
	Pour Date	1/25/01	1/25/01	1/25/01	1/29/01	1/29/01	1/29/01	1/30/01		
	1,4-Diethylbenzene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	2,3,5-Trimethylphenol	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	2,3-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	2,4,6-Trimethylphenol	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	2,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	2,5-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	2,6-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	2-Ethyltoluene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	3,4-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	3,5-Dimethylphenol	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	3-Ethyltoluene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	4-Ethyltoluene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Acenaphthalene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	a-Methylstyrene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Anthracene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Butylbenzene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Cyclohexane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Decane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Dodecane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Heptane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Indan	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Indene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Isobutylbenzene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Nonane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	n-Propylbenzene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Octane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A

Test Plan DX Individual Test Results – Lbs/Tn Metal

HAPS	COMPOUND / SAMPLE NUMBER	DX001	DX002	DX003	DX004	DX005	DX006	DX007	AVERAGE	STDEV
	Pour Date	1/25/01	1/25/01	1/25/01	1/29/01	1/29/01	1/29/01	1/30/01		
	p-Cymene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	sec-Butylbenzene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	tert-Butylbenzene	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Tetradecane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Tridecane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Undecane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
		Other Analytes								
	Carbon Monoxide	6.16E+00	6.43E+00	5.96E+00	6.15E+00	6.12E+00	5.84E+00	5.24E+00	5.99E+00	3.76E-01
	Methane	3.52E-01	4.04E-01	3.44E-01	3.51E-01	3.50E-01	3.34E-01	3.29E-01	3.52E-01	2.46E-02
	Carbon Dioxide	4.93E+01	5.36E+01	4.83E+01	5.21E+01	5.29E+01	4.51E+01	2.83E+01	4.71E+01	8.80E+00
	Ethane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Propane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Isobutane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Butane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Neopentane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Isopentane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Pentane	ND	ND	ND	ND	ND	ND	ND	N/A	N/A
	Condensables	2.18E+00	I	2.59E+00	N/A	N/A	N/A	2.09E+00	2.28E+00	2.70E-01
	Acetone	3.22E-02	4.77E-02	3.01E-02	2.93E-02	3.91E-02	2.50E-02	3.60E-02	3.42E-02	7.51E-03

I: Data was rejected based on data validation considerations.
All "Other Analytes" are not included in the sum of HAPs or VOCs.
N/A: Not Applicable; NT: Not Tested; ND: Non Detect

APPENDIX C TEST SERIES DG AND DX DETAILED PROCESS AND SOURCE DATA

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Test DG Process and Source Data

Description	DG001	DG002	DG003	DG004	DG005	DG006	DG007	DG008	DG009
	11/13/00	11/13/00	11/13/00	11/14/00	11/14/00	11/14/00	11/14/00	11/15/00	11/15/00
Casting Metal Weight, lbs. (Note 1)	132	130	111	134	**136**	**138**	**123**	**130**	**129**
Total No Bake Mold Weight, lbs.	332	333	339	326	**329**	**332**	**334**	**333**	**334**
Total Binder Weight including catalyst, lbs	3.813	3.824	3.893	4.003	**4.040**	**4.076**	**4.101**	**3.775**	**3.786**
No. Cavities Poured (four-on gears)	4	4	4	4	**4**	**4**	**4**	**4**	**4**
No Bake Mold LOI, % 1400°F	1.24	1.23	1.17	1.49	**1.25**	**1.39**	**1.23**	**1.52**	**1.68**
Pouring Temperature, °F	2640	2638	2635	2626	**2636**	**2640**	**2622**	**2636**	**2638**
Dog Bone Tensile Strength 30 min., psi	115.00	109.67	86.67	102.67	**123.67**	**103.67**	**87.00**	**129**	**82.83**
Dog Bone Tensile Strength 2 hrs, psi	151.00	147.83	145.00	209.67	**198.33**	**200.33**	**203.67**	**237.33**	**200.50**
Dog Bone Tensile Strength 24 hrs, psi	181.17	182.17	196.67	274.83	**239.33**	**221.17**	**239.00**	**200.67**	**179.17**
Dog Bone Tensile Strength 24 hrs at 90% RH, si	61.50	61.00	62.00	64.83	**64.17**	**107.17**	**105.50**	**73.00**	**85.17**
Sand Flow Rate, lbs / 15 seconds	58.60	58.60	58.60	55.00	**55.00**	**55.00**	**55.00**	**59.50**	**59.50**
Resin(part I+part II), % BOS	1.12	1.12	1.12	1.20	**1.20**	**1.20**	**1.20**	**1.10**	**1.10**
Resin Part 1, grams	160.40	160.40	160.40	161.90	**161.90**	**161.90**	**161.90**	**163.50**	**163.50**
Co-reactant Part 2, grams	137.20	137.20	137.20	137.10	**137.10**	**137.10**	**137.10**	**134.50**	**134.50**
Catalyst Part 3, BO Pt.1, grams	11.50	11.50	11.50	11.40	**11.40**	**11.40**	**11.40**	**11.70**	**11.70**
Total Binder, true %(resins + catalyst)	1.15	1.15	1.15	1.23	**1.23**	**1.23**	**1.23**	**1.13**	**1.13**
Total Binder, true %(resins only)	1.11	1.11	1.11	1.18	**1.18**	**1.18**	**1.18**	**1.09**	**1.09**
Average Stack Temperature, °F	-	-	-	-	**105**	**109**	**111**	**97**	**104**
Total Moisture Content, %	-	-	-	-	**0.94**	**0.98**	**0.94**	**0.78**	**0.78**
Average Stack Velocity, ft./sec.	-	-	-	-	**15.90**	**15.90**	**15.90**	**16.20**	**15.80**
Avg. Stack Pressure, in. Hg	-	-	-	-	**30.14**	**30.10**	**30.09**	**30.24**	**30.23**
Stack Flow Rate, scfm	-	-	-	-	**697**	**693**	**693**	**727**	**699**

Binder fraction = binder including catalyst(lbs)/(sand + binder including catalyst(lbs)). Binder fraction x mold weight used in mold = Total Binder Weight including catalyst.
Ex.:(0.6808/(58.6 + 0.6808)) = 0.0114. 0.0114x 332 = 3.785 (lbs binder per mold) 1.1% No Bake resin DG001-013
Ex.:(0.6637/(58.5 + 0.6637)) = 0.0112. 0.0112 x 324 = 3.635 (lbs binder per mold) 1.1% No Bake resin DG018-021
NOTE 1: Casting metal used is Iron. Rebar hangers excluded from casting weight.
NOTE 2: Dog Bone Tensile Strength values are the average of six samples.
NOTE 3: No stack data for tests DG001-004 was recorded, therefore, these tests will not be used for comparisons.
NOTE 4: Test pours DG014 and DG017 were run-outs. DG015, no hangers were installed and DG016 was mfr'd incorrectly.
NOTE 5: Casting DG003 had shorter than acceptable pour sprue.
NOTE 6: Tests DG018, DG020 and DG021 will not be used in the comparison averages due to LOI and Dogbone tensile strength value ranges. DG012 will not be used in comparison averages due to incomplete LOI data.
NOTE 7: Tests in bold type are used for the report comparison.

Test DG Process and Source Data

Description	DG010	DG011	DG012	DG013	DG018	DG019	DG020	DG021	Average of DG001-021
	11/15/00	11/15/00	11/16/00	11/16/00	12/27/00	12/27/00	12/27/00	12/27/00	
Casting Metal Weight, lbs. (Note 1)	**132**	**134**	132	**131**	133	**127**	124	136	130
Total No Bake Mold Weight, lbs.	**334**	**332**	330	**333**	325	**324**	314	321	330
Total Binder Weight including catalyst, lbs	**3.786**	**3.763**	3.822	**3.857**	3.646	**3.634**	3.522	3.601	3.820
No. Cavities Poured (four-on gears)	**4**	**4**	4	**4**	4	**4**	4	4	4
No Bake Mold LOI, % 1400°F	**1.35**	**1.46**	ND	**1.64**	0.99	**1.16**	0.97	1.22	1.31
Pouring Temperature, °F	**2658**	**2631**	2628	**2636**	2622	**2652**	2622	2640	2635
Dog Bone Tensile Strength 30 min., psi	**103.00**	**78.67**	85.50	**129.67**	35.83	**84.67**	72.50	89.83	95.29
Dog Bone Tensile Strength 2 hrs, psi	**242.00**	**212.17**	256.50	**234.17**	95.17	**145.33**	124.83	122.83	183.92
Dog Bone Tensile Strength 24 hrs, psi	**260.17**	**186.67**	241.17	**240.33**	207.50	**207.00**	191.67	163.83	212.50
Dog Bone Tensile Strength 24 hrs at 90% RH, psi	**80.33**	**104.67**	86.17	**96.00**	68.83	**63.67**	61.83	49.00	76.17
Sand Flow Rate, lbs / 15 seconds	**59.50**	**59.50**	59.00	**59.00**	58.50	**58.50**	58.50	58.50	57.99
Resin(part I+part II), % BOS	**1.10**	**1.10**	1.13	**1.13**	1.10	**1.10**	1.10	1.10	1.13
Resin Part 1, grams	**163.50**	**163.50**	161.50	**161.50**	156.90	**156.90**	156.90	156.90	160.79
Co-reactant Part 2, grams	**134.50**	**134.50**	140.40	**140.40**	134.00	**134.00**	134.00	134.00	136.16
Catalyst Part 3, BO Pt.1, grams	**11.70**	**11.70**	12.00	**12.00**	10.40	**10.40**	10.40	10.40	11.32
Total Binder, true %(resins + catalyst)	**1.13**	**1.13**	1.16	**1.16**	1.12	**1.12**	1.12	1.12	1.16
Total Binder, true %(resins only)	**1.09**	**1.09**	1.11	**1.11**	1.08	**1.08**	1.08	1.08	1.12
Average Stack Temperature, °F	**107**	**108**	97	**101**	99	**106**	111	111	105
Total Moisture Content, %	**0.89**	**0.97**	0.74	**0.79**	0.86	**0.92**	0.92	0.9	0.88
Average Stack Velocity, ft./sec.	**16.40**	**16.40**	15.70	**15.80**	15.70	**15.80**	15.90	16.40	15.98
Avg. Stack Pressure, in. Hg	**30.19**	**30.15**	30.12	**30.12**	30.35	**30.30**	30.31	30.26	30.20
Stack Flow Rate, scfm	**719**	**718**	703	**700**	703	**698**	695	718	705

Binder fraction = binder including catalyst(lbs)/(sand + binder including catalyst(lbs)). Binder fraction x mold weight used in mold = Total Binder Weight including catalyst.

Ex.: (0.6808/(58.6 + 0.6808)) = 0.0114. 0.0114x 332 = 3.785 (lbs binder per mold) 1.1% No Bake resin DG001-013

Ex:(0.6637/(58.5 + 0.6637)) = 0.0112. 0.0112 x 324 = 3.635 (lbs binder per mold) 1.1% No Bake resin DG018-021

NOTE 1: Casting metal used is Iron. Rebar hangers excluded from casting weight.

NOTE 2: Dog Bone Tensile Strength values are the average of six samples.

NOTE 3: No stack data for tests DG001-004 was recorded, therefore, these tests will not be used for comparisons.

NOTE 4: Test pours DG014 and DG017 were run-outs. DG015, no hangers were installed and DG016 was mfr'd incorrectly.

NOTE 5: Casting DG003 had shorter than acceptable pour sprue.

NOTE 6: Tests DG018, DG020 and DG021 will not be used in the comparison averages due to LOI and Dogbone tensile strength value ranges. DG012 will not be used in comparison averages due to incomplete LOI data.

NOTE 7: Tests in bold type are used for the report comparison.

Test DX Process and Source Data

Description	DX001	DX002	DX003	DX004	DX005	DX006	DX007	Averages	Averages
	1/25/01	1/25/01	1/25/01	1/29/01	1/29/01	1/29/01	1/30/01	all	for report
Casting Metal Weight, lbs. (Note 1)	138	118	126	124	122	140	145	130	133
Total No Bake Mold Weight, lbs.	394	394	385	383	389	385	380	387	386
Total Binder Weight including catalyst, lbs	7.057	7.057	6.895	6.828	6.935	6.864	6.766	6.91	6.89
No. Cavities Poured (four-on gears)	4	4	4	4	4	4	4	4	4
No Bake Mold LOI, % 1400°F	2.15	2.30	2.21	2.37	2.40	2.30	2.11	2.26	2.26
Pouring Temperature, °F	2620	2620	2620	2628	2640	2635	2636	2628	2630
Dog Bone Tensile Strength 30 min., psi	39	46	36	21	51	42	30	38	36
Dog Bone Tensile Strength 2 hrs, psi	111	107	Note 7	88	106	63	44	86	82
Dog Bone Tensile Strength 24 hrs, psi	170	201	158	145	187	156	108	161	154
Dog Bone Tensile Strength 24 hrs at 90% RH, psi	116	132	97	120	134	116	64	111	108
Sand Flow Rate, lbs / 15 seconds	49.00	49.00	49.00	49.00	49.00	49.00	49.50	49.07	49.08
Resin(part I), % BOS	1.30	1.30	1.30	1.30	1.30	1.30	1.29	1.30	1.30
Resin Part 1, grams	289.60	289.60	289.60	288.70	288.70	288.70	289.70	289.23	289.17
Co-reactant Part 2, grams	116.10	116.10	116.10	115.10	115.10	115.10	117.70	115.90	115.87
Catalyst Part 3, BO Pt.1, grams	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Binder, true %(resin + coreactant)	1.79	1.79	1.79	1.78	1.78	1.78	1.78	1.79	1.79
Total Resin, true %(resin only)	1.29	1.29	1.29	1.28	1.28	1.28	1.27	1.28	1.28
Average Stack Temperature, °F	104	106	104	102	107	112	109	106	106
Total Moisture Content, %	0.96	0.97	0.97	1.00	1.04	1.09	0.72	0.96	0.96
Average Stack Velocity, ft./sec.	16.3	16.1	16.1	16.0	15.8	15.9	16.1	16.0	16.0
Avg. Stack Pressure, in. Hg	30.20	30.18	30.06	30.25	30.30	30.31	30.32	30.23	30.24
Stack Flow Rate, scfm	721	708	708	711	697	694	709	707	707

Binder fraction = binder including catalyst(lbs)/(sand + binder including catalyst(lbs)). Binder fraction x mold weight used in mold = Total Binder Weigh including catalyst.
Example: (0.8936/(49 + 0.8936)) = 0.0179. 0.0179x 394 = 7.057 (lbs binder per mold) 1.3% No Bake resin DX001-007

NOTE 1: Casting metal used is Iron.
NOTE 2: DX001 - Shake-out was not functioning correctly due to the bungee breaking.
NOTE 3: DX002 had short castings caused by metal leakage.
NOTE 4: DX004 and 005 each have a short sprue caused by metal leakage.
NOTE 5: Molds for DX004-006 were made on 1-25-01 and poured on 1-29-01
NOTE 6: Dog Bone Tensile Strength values are the average of six samples.
NOTE 7: Dog Bone Tensile Strength for DX003, 2 hour tests were not done..
NOTE 8: Dog Bone Tensile Strength values are the average of three samples for DX007, ran out of sand
NOTE 9: **ND** means no data available.
NOTE 10: High LOI's are the result of the large catalyst content of 40% and carbonate decomposition at test temperatures. Expected LOI is 2.12-2.32%.

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APPENDIX D METHOD 25A CHARTS

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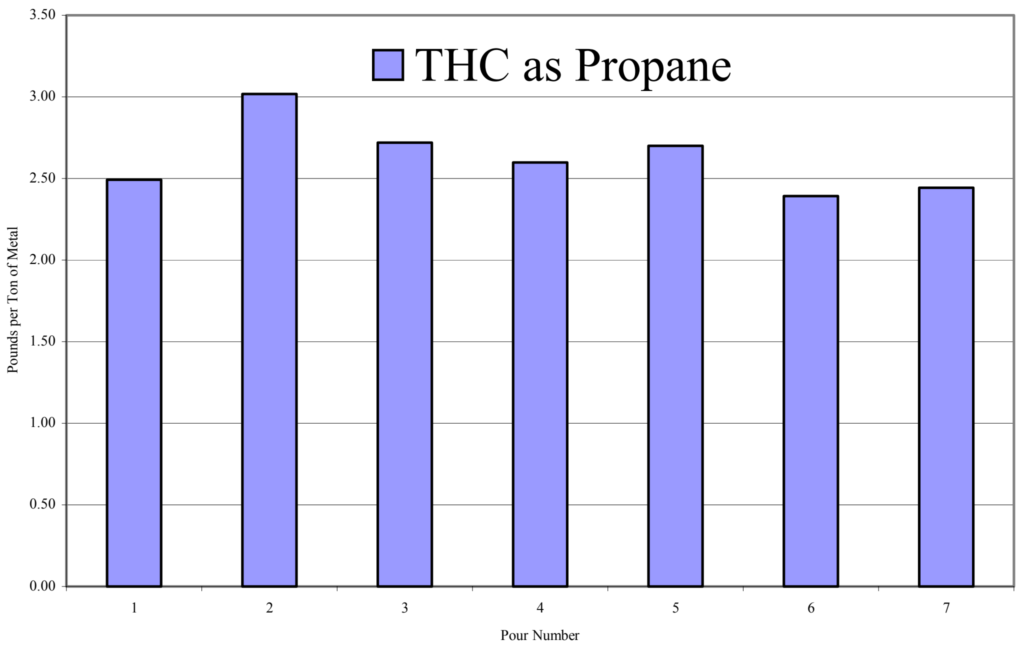
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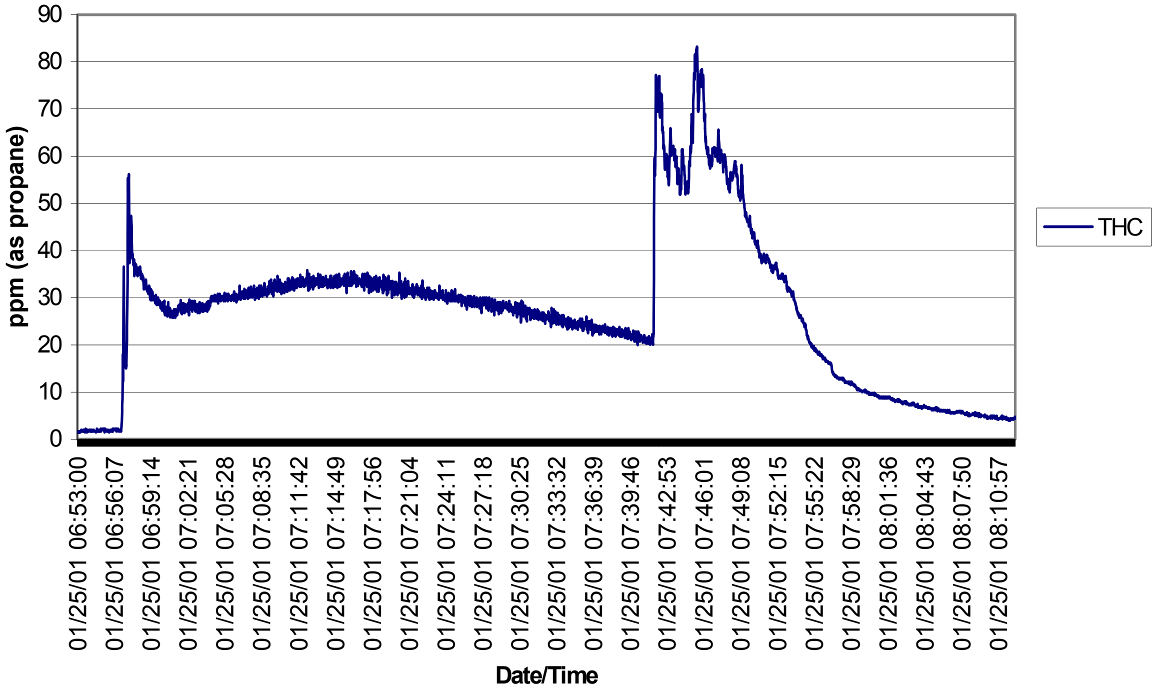
1
2
3
4
5
6
7
Pour Number

DX001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80
70
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THC
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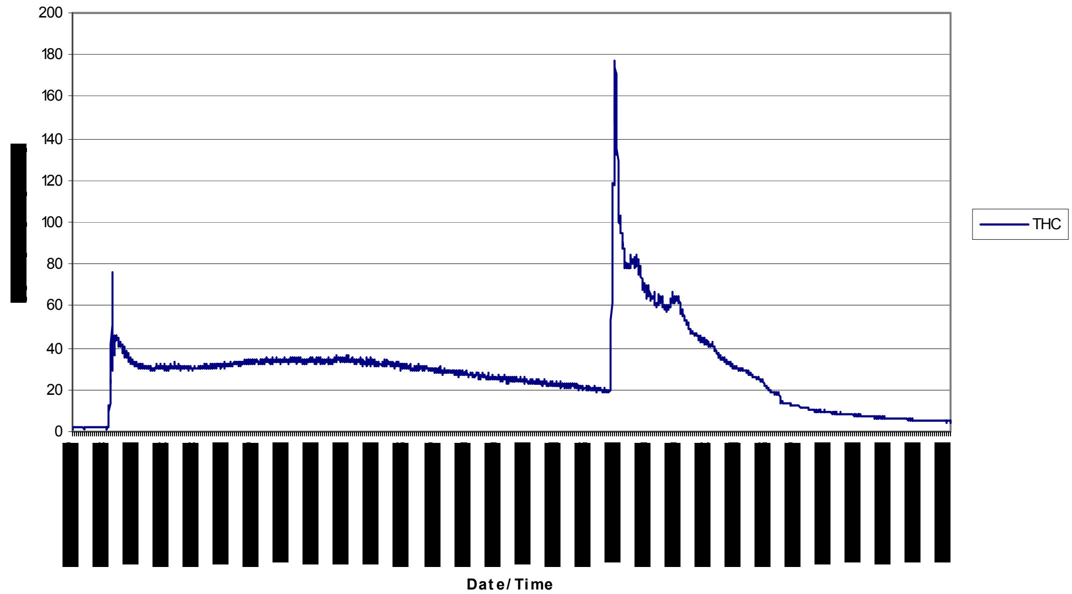
Date/Time

DX002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80
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40
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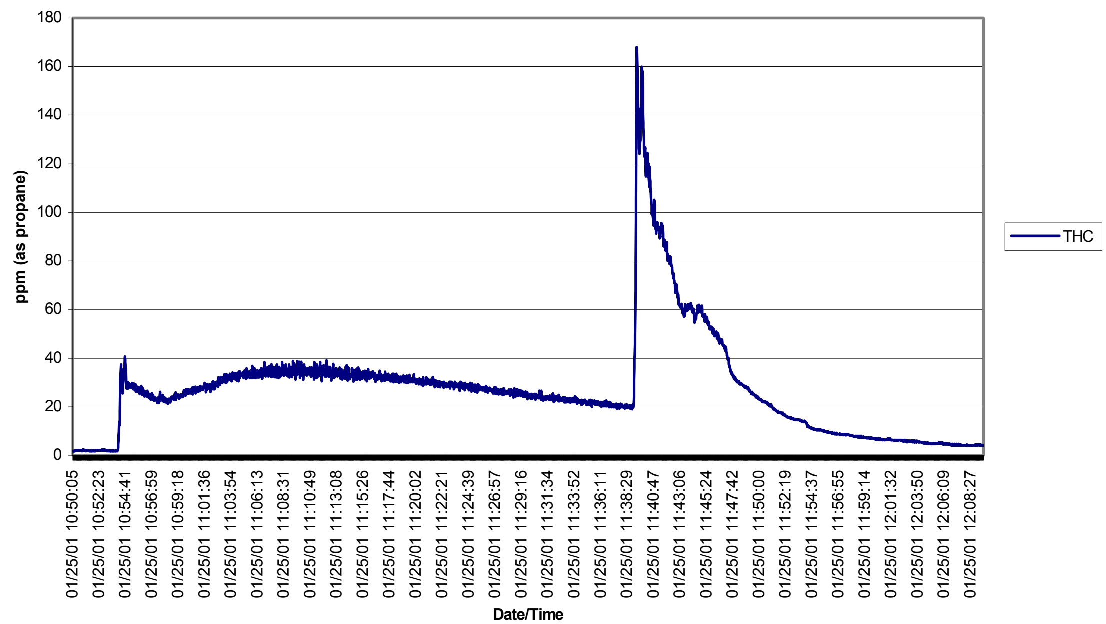
THC
Date/Time

DX003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140
120
100
80
60
40
20
0
ppm (as propane)
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01/25/01 10:54:41
01/25/01 10:56:59
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01/25/01 11:01:36
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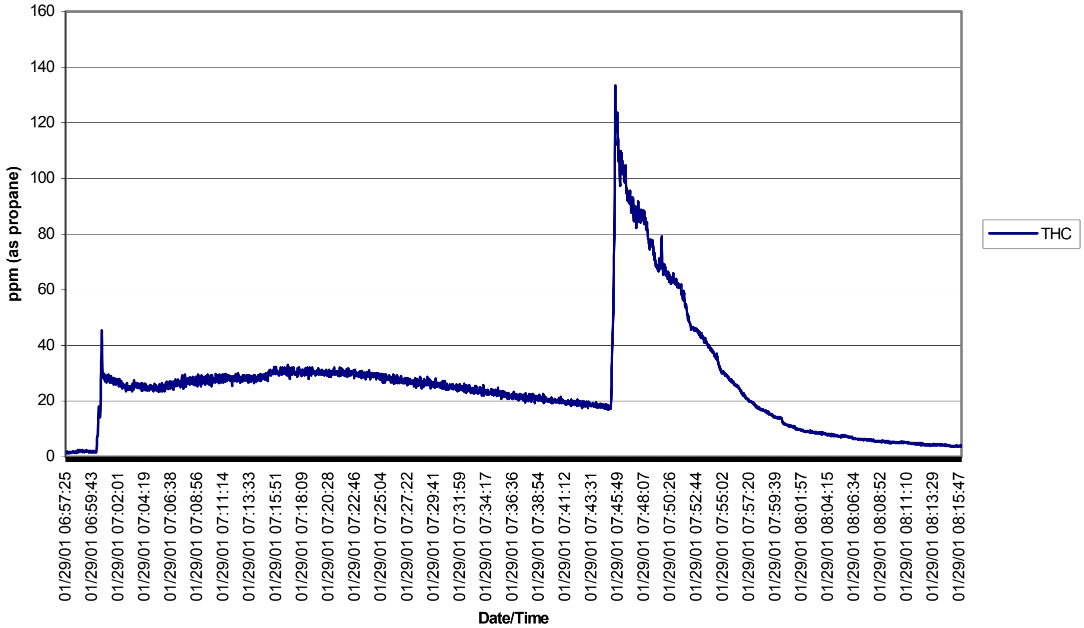
Date/Time

DX004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120
100
80
60
40
20
0
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THC
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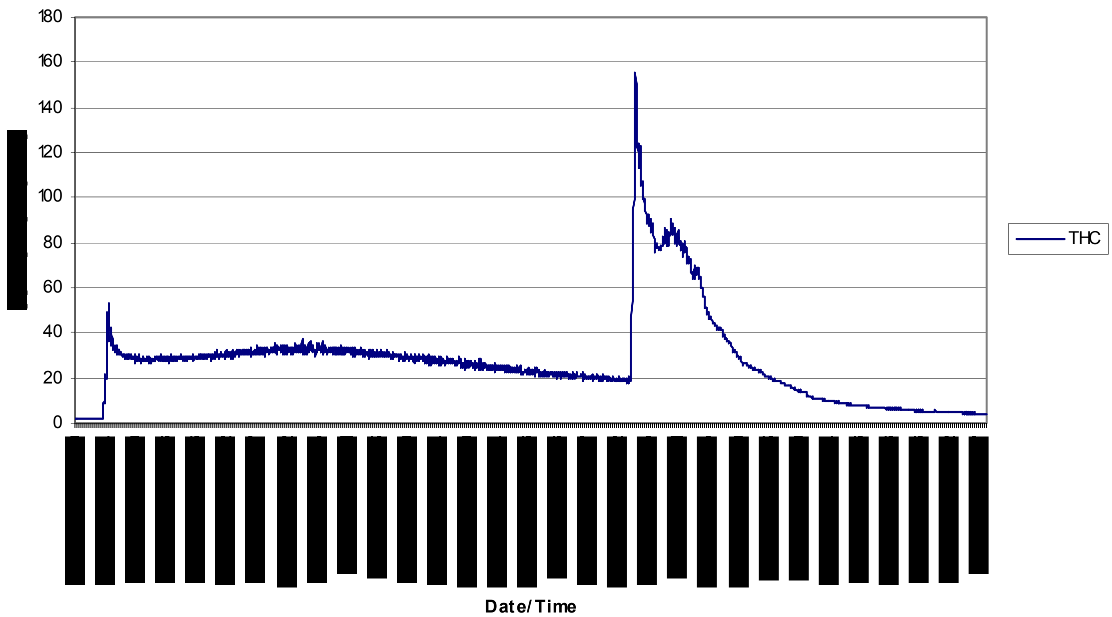
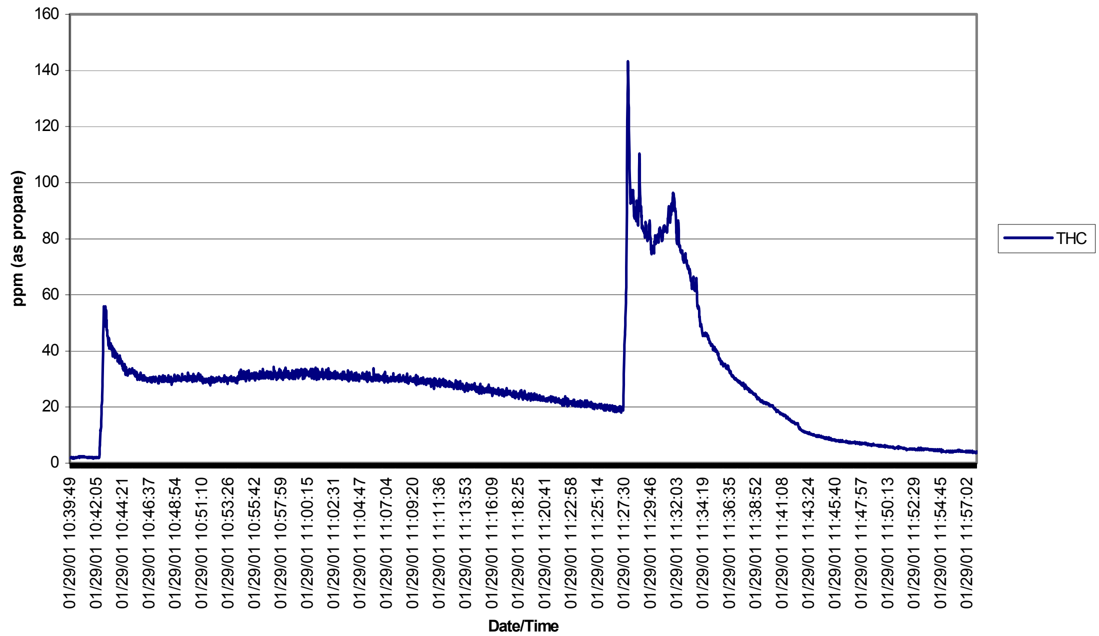
01/29/01 07:52:44
01/29/01 07:55:02
01/29/01 07:57:20
01/29/01 07:59:39
01/29/01 08:01:57
01/29/01 08:04:15
01/29/01 08:06:34
01/29/01 08:08:52
01/29/01 08:11:10
01/29/01 08:13:29
01/29/01 08:15:47
Date/Time

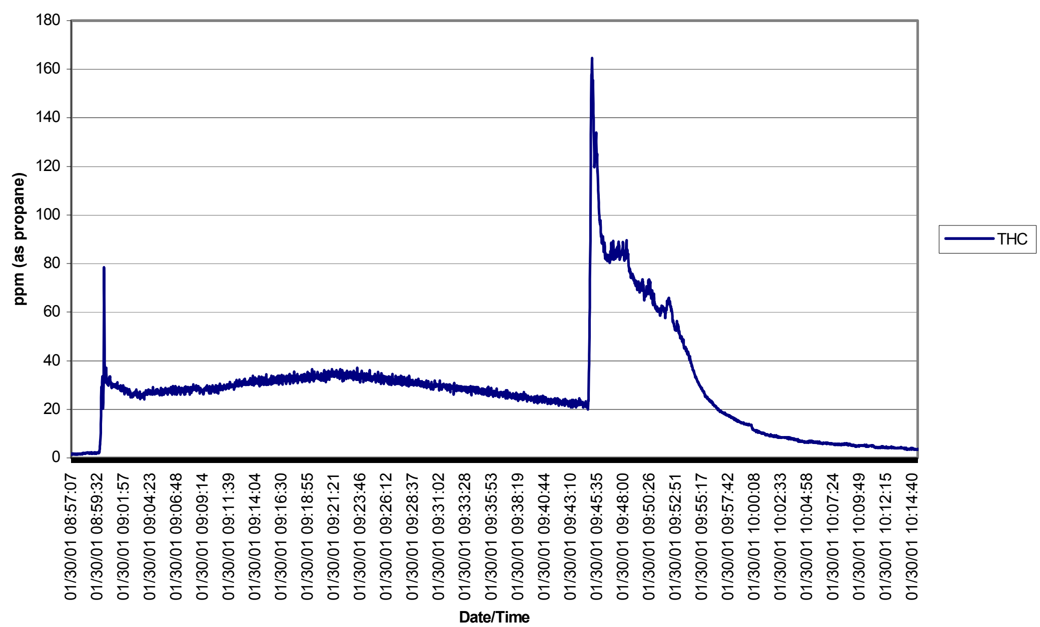
DX005


180
160
140
120
100
80
60
40
20
0
[redacted]
THC
[redacted]
Date/Time

DX006


ppm (as propane)
160
140
120
100
80
60
40
20
0
THC
Date/Time
01/29/01 10:39:49
01/29/01 10:42:05
01/29/01 10:44:21
01/29/01 10:46:37
01/29/01 10:48:54
01/29/01 10:51:10
01/29/01 10:53:26
01/29/01 10:55:42
01/29/01 10:57:59
01/29/01 11:00:15
01/29/01 11:02:31
01/29/01 11:04:47
01/29/01 11:07:04
01/29/01 11:09:20
01/29/01 11:11:36
01/29/01 11:13:53
01/29/01 11:16:09
01/29/01 11:18:25
01/29/01 11:20:41
01/29/01 11:22:58
01/29/01 11:25:14
01/29/01 11:27:30
01/29/01 11:29:46
01/29/01 11:32:03
01/29/01 11:34:19
01/29/01 11:36:35
01/29/01 11:38:52
01/29/01 11:41:08
01/29/01 11:43:24
01/29/01 11:45:40
01/29/01 11:47:57
01/29/01 11:50:13
01/29/01 11:52:29
01/29/01 11:54:45
01/29/01 11:57:02

DX007


ppm (as propane)
180
160
140
120
100
80
60
40
20
0
THC
Date/Time
01/30/01 08:57:07
01/30/01 08:59:32
01/30/01 09:01:57
01/30/01 09:04:23
01/30/01 09:06:48
01/30/01 09:09:14
01/30/01 09:11:39
01/30/01 09:14:04
01/30/01 09:16:30
01/30/01 09:18:55
01/30/01 09:21:21
01/30/01 09:23:46
01/30/01 09:26:12
01/30/01 09:28:37
01/30/01 09:31:02
01/30/01 09:33:28
01/30/01 09:35:53
01/30/01 09:38:19
01/30/01 09:40:44
01/30/01 09:43:10
01/30/01 09:45:35
01/30/01 09:48:00
01/30/01 09:50:26
01/30/01 09:52:51
01/30/01 09:55:17
01/30/01 09:57:42
01/30/01 10:00:08
01/30/01 10:02:33
01/30/01 10:04:58
01/30/01 10:07:24
01/30/01 10:09:49
01/30/01 10:12:15
01/30/01 10:14:40

APPENDIX F LISTING OF SUPPORT DOCUMENTS

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Listing of Support Documents

The following documents contain specific test results, procedures, and documentation used in support of this Test Plan

1. Casting Emission Reduction Program – Foundry Product Testing Guide: Reducing Emissions by Comparative Testing, May 4, 1998.

2. Technikon Emissions Testing and Analytical Testing Standard Operating Procedures.

3. Emission Baseline Test Results for the CERP Pre-Production Foundry Processes.

4. Evaluation of the Required Number of Replicate Tests to Provide Statistically Significant Air Emission Reduction Comparisons for the CERP Pre-Production Foundry Test Program.

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APPENDIX G GLOSSARY

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Glossary

t-Test The calculated T statistic, Ts, is compared against a table value. The table value is a function of the sample size and on the level of confidence desired. For tests with nine sample values each, the T value associated with a confidence level of 95% is 2.12. Calculated values of Ts greater than or equal to this value would indicate that there is 95% or better probability that the differences between the two test series were not the result of test variability.

ND Non Detect, No Data

NT Lab testing was not done on this analyte.

HC as Hexane Calculated by the summation of all area between elution of Hexane through the elution of Hexadecane. The quantity of HC is performed against a five-point calibration curve of Hexane by dividing the total area count from C6 through C16 to the area of Hexane from the initial calibration curve.

POM Polycyclic Organic Matter (POM) including Naphthalene and other compounds that contain more than one benzene ring and have a boiling point greater than or equal to 100 degrees Celsius.

LOI Loss of Ignition. LOI represents the change in weight of a sample expressed as % of the original dry weight as a consequence of combustion in air at the test temperature of 1400˚F